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*Scientific Research and Consulting*

# RISK ASSESSMENT OF ENVIRONMENTAL TRITIUM AT LAWRENCE BERKELEY NATIONAL LABORATORY

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**Prepared for:**

**Lawrence Berkeley National Laboratory**

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# EXECUTIVE SUMMARY

This report presents an evaluation of human health and ecological risks associated with environmental tritium releases from the National Tritium Labeling Facility (NTLF) at the Lawrence Berkeley National Laboratory (Berkeley Lab), in Berkeley, California. This report was prepared to supplement information being supplied by the Berkeley Lab to the United States Environmental Protection Agency (EPA) to provide additional information to the Agency for its determination of whether the Lab should be proposed for listing on the National Priorities List (NPL) under the federal Superfund Program.

The risk evaluation followed EPA guidelines for conducting baseline risk assessments at Superfund sites, and was based on supplemental sampling data collected during 2001 to satisfy EPA and stakeholder groups' requests for more data on environmental tritium in the vicinity of the NTLF. Samples were collected in accordance with approved sampling plans from environmental media at and surrounding locations of likely maximum concentration. Risks were evaluated for all potential receptors and exposure pathways.

## Sampling Results

Tritium was detected in ambient air and soils. Overall, the supplemental sampling data support the historically reported trends of maximum tritium concentrations near the stack, commonly in a predominant wind direction. Concentrations at more distant locations are substantially lower and, in many cases, at or near background levels for the region. Tritium was detected in a single sediment sample and two surface water samples from area creeks, but at concentrations orders of magnitude below health-protective standards.

## Exposure Assessment

The principal pathways by which humans can potentially be exposed to environmental tritium in the vicinity of the NTLF are via inhalation and dermal absorption of tritiated water vapor (HTO) that is present in ambient air. No other pathways are complete or contribute substantially to risk. For example, tritium levels in soil, even in the maximum concentration areas near the NTLF stacks, are two to three orders of magnitude below risk-based soil screening levels developed for the protection of human health. Surface water and sediment exposures also do not contribute significantly to risks given the no or low detected tritium levels and the low likelihood that these water bodies would be used recreationally. Groundwater exposure also is not a factor, as groundwater is not used as a public water source in the vicinity of the site. Exposure to tritium from the ingestion of produce grown on local residential soil is theoretically possible, but tritium was not detected in the soil samples collected from any residential location. Tritium also can be present in locally grown produce as a result of water vapor uptake directly from air, but this pathway does not contribute significantly to overall risks.

Intake associated with potential inhalation and dermal exposure to airborne HTO was calculated for three receptor populations: Berkeley Lab workers located closest to the NTLF, nearby residents, and residents at a background location. Exposures were calculated assuming workers and residents were exposed for 25 and 30 years, respectively, consistent with EPA Superfund guidance. Ambient air concentrations during these exposure periods were conservatively assumed to remain unchanged. This is a significant overestimate because it does not take into account the scheduled closing of the NTLF in December 2001. After the closure and cleanup of the NTLF, emissions will decrease significantly and HTO concentrations in air should approach regional background levels.

## Risk Characterization

Risk coefficients developed by EPA were used to calculate excess lifetime risk associated with airborne exposure to HTO. The risk coefficient is an estimate of the probability of radiogenic cancer morbidity per unit activity inhaled or ingested. A risk coefficient may be interpreted as the average risk per unit exposure for persons exposed throughout life to a constant activity concentration of a radionuclide in an environmental medium.

Total excess lifetime cancer risks from inhalation and dermal absorption of airborne HTO were calculated to be in the range of $10^{-7}$ to $10^{-8}$. These risks fall below EPA's risk range of $10^{-4}$ to $10^{-6}$ for risk management action at Superfund sites, and will likely be even lower following the closure of the NTLF in December 2001. In addition, environmental tritium associated with the NTLF does not pose a noncarcinogenic hazard or a risk to ecological receptors at the site or surrounding area.

## Conclusions

The collective results of supplemental environmental sampling interpreted by this baseline risk evaluation demonstrate that the tritium concentrations at the Berkeley Lab are well below the Applicable or Relevant and Appropriate Requirements that would apply under Superfund, and that environmental tritium associated with the NTLF at the Berkeley Lab does not pose any risk that would require remedial or response activities under the federal Superfund program. These results corroborate the results of prior risk assessments and public health evaluations, which demonstrate that the operation of the NTLF does not pose a significant risk to human health or the environment. The results also are consistent with National Emission Standards for Hazardous Air Pollutants requirements. For these reasons, the Berkeley Lab should not be considered for inclusion on the NPL.

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# 1.0 INTRODUCTION

This report presents an evaluation of human health and ecological risks associated with environmental tritium releases from the National Tritium Labeling Facility (NTLF) at the Lawrence Berkeley National Laboratory (Berkeley Lab), in Berkeley, California. This report was prepared to supplement information being supplied by the Berkeley Lab to the United States Department of Energy (DOE) and to the United States Environmental Protection Agency (EPA) to support EPA's determination of whether the Lab should be proposed for listing on the National Priorities List (NPL) under the federal Superfund Program. In 1998, EPA determined that the site was potentially eligible for listing on the NPL (EPA 1998a). However, EPA deferred a decision on whether to propose the Berkeley Lab for NPL listing and requested that additional air, soil, sediment and surface water samples be collected from the Berkeley Lab and the surrounding area. Specifically, EPA requested supplemental ambient air, soil, surface water and sediment sampling for tritium. In response to this request, the Berkeley Lab prepared detailed sampling plans (LBNL 2001a-d) that were reviewed by EPA and approved by DOE after a substantial amount of public participation. Supplemental sampling began in the spring of 2001 and will continue until the spring of 2002.

The risk assessment presented in this report is based upon the first several months of supplemental data. During these initial months, all of the soil samples and the majority of the sediment and surface water samples were collected, along with three months of ambient air samples. Even though additional data remain to be collected until May 2002, this risk assessment has been prepared at this time because the supplemental data compiled to date are fully consistent with the volumes of data and site characterizations that have previously been collected and prepared for the NTLF.

## 1.1 Purpose of the Assessment

This risk assessment has been prepared to assist DOE and EPA in their review of the supplemental monitoring data and to aid in EPA's NPL listing evaluation of the Berkeley Lab.

The risk evaluation presented here follows EPA guidelines for conducting baseline risk assessments at NPL sites (EPA 1989a, 1991a, 1998b, 1999a, 2000a, 2001). Under EPA guidance, sites that are listed on the NPL normally go through a remedial investigation and feasibility study (RI/FS) to determine the need for or extent of any necessary environmental clean-up. The data generated by the RI/FS are used in the baseline risk assessment. EPA uses baseline risk assessments throughout the RI/FS process to:

- determine if an imminent and substantial threat to human health or the environment exists,
- determine the extent of the regulatory response to such a threat, and
- evaluate competing remedial alternatives.

Given that the data available for this risk assessment of the Berkeley Lab were collected from all environmental media of concern identified by EPA, encompass areas of likely maximum concentration, and can be used to evaluate all potential exposure pathways in a manner consistent with EPA Superfund guidance, it is unlikely that any subsequent baseline risk assessment conducted by the Agency would identify risks greater than that presented here. Therefore, this risk assessment should expedite EPA's review of the supplemental monitoring data and provide perspective on the issue of whether the Berkeley Lab should be proposed for listing on the NPL.

This risk assessment was prepared by CPF Associates, Inc., a Washington DC-area based scientific research and consulting firm. CPF scientists conducted a site visit, reviewed historical environmental records associated with the NTLF, met with EPA Region IX, evaluated the usability of the data for risk assessment and conducted the risk assessment in accordance with EPA guidance. Co-principal investigators for this project were Dr. Paul Chrostowski and Ms. Judi Durda.

## 1.2 Scope of the Assessment

This risk assessment relies on environmental data collected in 2001 as part of a comprehensive sampling program of tritium implemented by the Berkeley Lab to satisfy EPA and stakeholder group requests for more data on tritium distribution and levels at the NTLF and in the surrounding area. EPA and stakeholder groups reviewed the sampling plans, and their comments were incorporated into the study design. EPA also independently analyzed split samples for tritium at some locations and separately validated Berkeley Lab-generated analytical data.

This risk assessment does not include an evaluation of other monitoring and modeling data collected during routine monitoring and modeling at the Berkeley Lab under other regulatory programs such as the Clean Air Act and the Resource Conservation and Recovery Act (RCRA). Although these data are technically adequate for addressing the requirements of the specific regulatory program under which they were generated, they do not consistently satisfy the particular administrative requirements unique to EPA's Superfund Program. These other data were considered during the design of the supplemental sampling program, however, and are summarized briefly here to provide historical context to the most recent sampling results.

This risk assessment also does not include an evaluation of supplemental vegetation monitoring data, which were collected in response to requests from stakeholders other than EPA. EPA did not request and will not use the supplemental vegetation data in determining the site's eligibility for the NPL.

Risks are assessed here based on the conservative assumption that the most recent sampling data are representative of current conditions and conditions that might exist in

the future. This assumption will probably overestimate risks, however, because the NTLF of the Berkeley Lab is scheduled to be closed in December 2001, and any routine emissions associated with that facility would cease[1] after the NTLF has been decontaminated and decommissioned. Absent a continuing source, tritium concentrations in the environment due to the NTLF should decline as tritium undergoes its decay from tritium to helium (which is not radioactive nor of concern from a chemical toxicity standpoint). The half-life of tritium is 12.3 years (NCRP 1979). In particular, ambient air tritium concentrations are expected to decrease after emissions from the NTLF are reduced.

Consistent with EPA risk assessment guidance, tritium risks evaluated in this report are expressed as excess lifetime cancer risks (based on morbidity) to exposed individuals. EPA (1999a) assumes that radiogenic cancer risk is the limiting risk from radionuclides at Superfund sites; evaluation of teratogenic and genetic or other adverse effects is not required. Similarly, with the exception of uranium, EPA does not require a risk evaluation based on the chemical toxicity of radionuclides. Uranium is the only radionuclide for which the chemical toxicity has been identified to be comparable to or greater than the radiotoxicity. EPA does not separately evaluate the chemical toxicity of tritium, and has not developed a non-cancer reference dose for this radionuclide.

## 1.3 Organization of this Report

This report is organized into five principal sections:

- **2.0 Site Background**. This section presents information on site location and operations, local land and water use and environmental setting, as well as on tritium sources and environmental tritium levels determined as part of routine compliance monitoring and during the supplemental sampling conducted during 2001.

- **3.0 Exposure Assessment.** This section discusses tritium environmental transport and fate and selects exposure pathways for evaluation in the risk assessment. Exposure point concentrations are calculated for each selected receptor population and pathway combination, and tritium intake (in units of picocuries (pCi)) is calculated for the exposed individual over a lifetime. The methods and assumptions used to support the calculations are described.

- **4.0 Toxicity Assessment.** This section presents a summary of the radiotoxicity of tritium and identifies the pathway-specific risk factors used to assess excess lifetime cancer risk.

1. Environmental monitoring and surveillance will continue throughout the NTLF closure activities.

- **5.0 Risk Characterization.** This section summarizes pathway-specific risks for each receptor group. The uncertainties associated with the risk estimates and the overall significance of the findings in the context of the EPA risk management framework also are discussed.

- **6.0 Ecological Assessment.** This section evaluates the potential for adverse effects from tritium exposure in the fish, wildlife, and plants inhabiting the site and surrounding area. The potential for impacts in the ecological communities of the San Francisco Bay also is discussed.

Section 7 presents overall summary and conclusions, and Section 8 lists literature cited.

## 2.0 SITE BACKGROUND[2]

Consistent with EPA risk assessment guidance (EPA 1998b), this section summarizes information on site location and operations, local land and water use and environmental setting, along with a summary of the scope and results of the environmental sampling program conducted by the Berkeley Lab in 2001. The results of routine sampling conducted by the Lab as part of regulatory compliance activities are also briefly summarized.

### 2.1 Site Location and Operations

The Berkeley Lab is located about three miles east of San Francisco Bay on land owned by the University of California (University or UC) (Figure 1). The Berkeley Lab's 200-acre main site is under long-term lease to DOE. The western portion of the Lab is in Berkeley, with the eastern portion in Oakland. The National Tritium Labeling Facility is located in Building 75 of the Berkeley Lab (Figure 2).

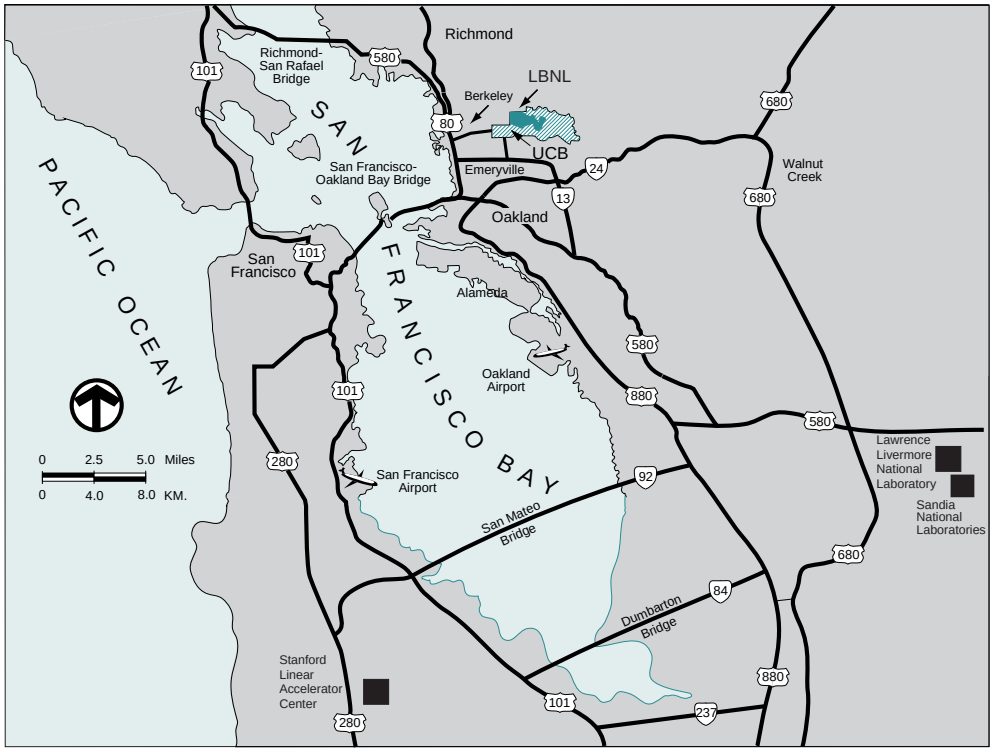


**Figure 1. Location of the Berkeley Lab**

2. Most of the information contained in this section has been derived directly from Site Environmental Reports (http://www.lbl.gov/ehs/epg/), site sampling plan documents (Lawrence Berkeley National Laboratory (2001a-d), a report by EPA (1998a), and the NTLF (http://www.lbl.gov/LBL-Programs/NTLF/NTLF_Dir_Page.html) and the Berkeley Lab Environment, Health and Safety (EH&S) (http://www.lbl.gov/ehs/) websites.

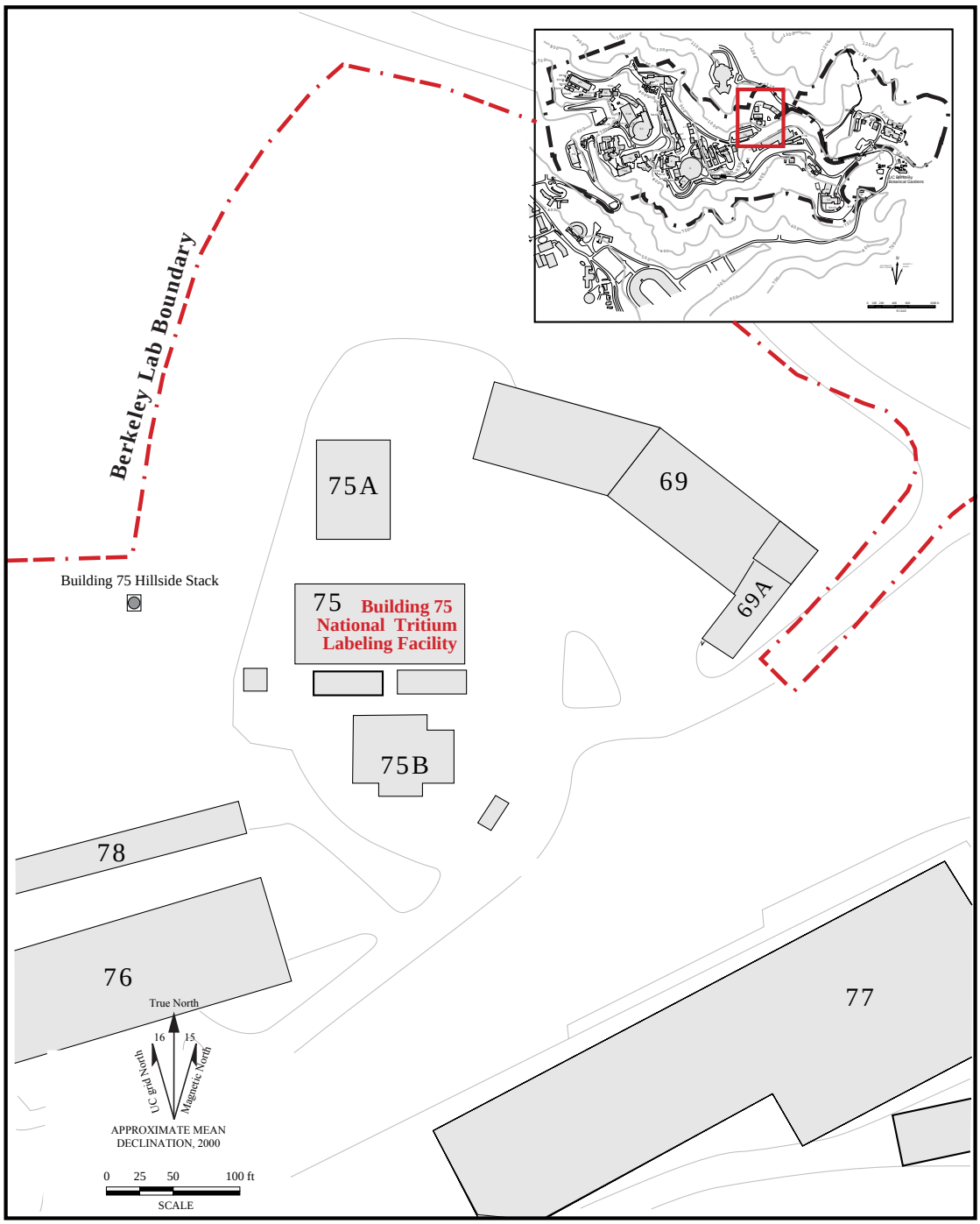


**Figure 2. Location of the NTLF within the Berkeley Lab**

Ernest O. Lawrence founded the Berkeley Lab in 1931, and the Lab currently performs research in such diverse fields as fundamental physics, energy conservation technology, materials science, structural biology, medical imaging, and advanced battery technologies. Berkeley Lab is managed by the University under contract with the Department of Energy.

Tritium research has occurred in Building 75 since 1969. The NTLF was established in 1982 as a National Institutes of Health (NIH) national resource center at Berkeley Lab. The facility's role has been to conduct research and supply educational and tritium labeling support for biomedical researchers in North America.

## 2.2 Land and Water Use

Land use in the vicinity of the Berkeley Lab consists of residential, institutional, and recreational areas. The area to the south and east, which is University land, is maintained largely in a natural state and includes the University recreational facilities and Botanical Garden. The University's Lawrence Hall of Science, Space Sciences Laboratory, and Mathematical Sciences Research Institute are located north and northeast of the NTLF. The Berkeley Lab is bordered on the north by single-family homes and on the west by the UC Berkeley campus as well as multi-unit dwellings, student residence halls, and private homes. The area to the west of Berkeley Lab is highly urbanized. Figure 3 displays the distribution of land use surrounding Berkeley Lab.

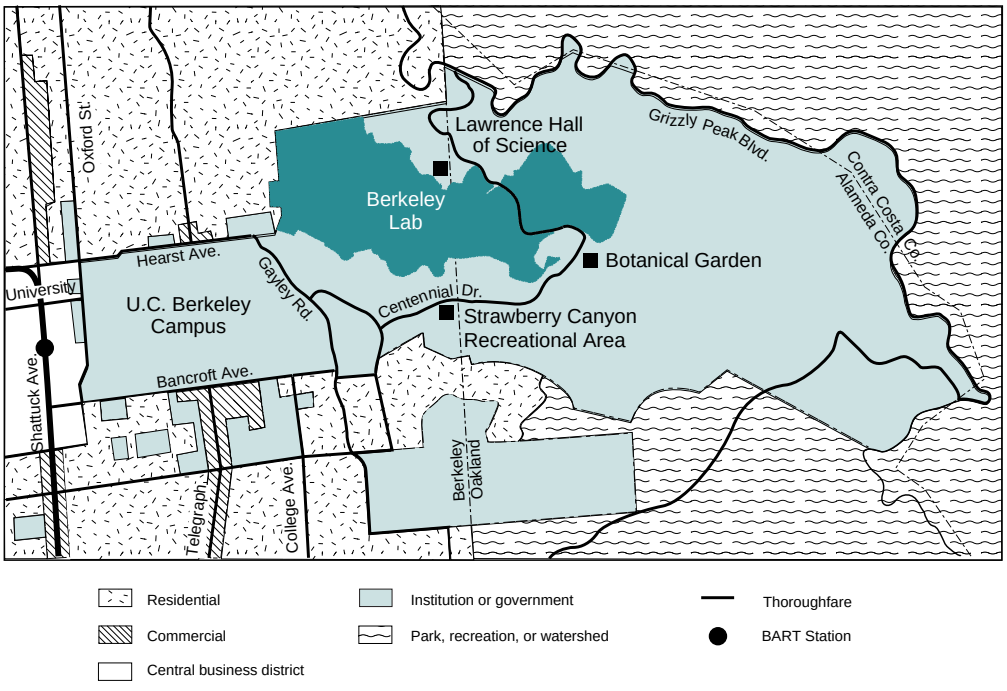


**Figure 3. Land use adjacent to the Berkeley Lab**

The East Bay Municipal Utility District (EBMUD) supplies domestic water for the Lab and surrounding communities (EPA 1998a). The water originates in Sierra Nevada watershed lands and is transported to the Bay Area and ultimately to Berkeley Lab through a system of lakes, aqueducts, treatment plants, and pumping stations. No public drinking water supply wells are within 4 miles of the Berkeley Lab. Therefore it is unlikely that local groundwater is used or will be used as an alternative drinking water source by individual residences in the vicinity (EPA 1998a).

## 2.3 Environmental Setting

### 2.3.1 Meteorology

The site's climate is temperate, influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west and the ridgeline to the east that stretches along the eastern shore of San Francisco Bay. These physical barriers contribute significantly to the site's relatively warm, wet winters and cool, dry summers.

On-site wind patterns change little from one year to the next. The most prevalent wind pattern occurs during fair weather, with daytime westerly winds blowing off the Bay, followed by lighter nighttime southeasterly winds originating in the East Bay hills. The other predominant wind pattern is associated with storm systems passing through the region, which usually occurs during the winter months. South-to-southeast winds in advance of each storm are followed by a shift to west or northwest winds after passage of the storm system. A graphical summary of the annual wind patterns (windrose) is presented in Figure 4.

### 2.3.2 Geology/Hydrogeology

The Berkeley Lab occupies the west- and south-facing slopes of the Berkeley hills immediately east of the main University campus. Elevations range from approximately 550 feet to 1,100 feet above sea level. The Berkeley Lab site is underlain by sedimentary and volcanic rocks with interbedding and folding that have created a complex geological structure. Major faults exist on both sides of the Lab. In general, the bedrock is relatively weak and has weathered deeply, forming soils several feet thick. In many areas, landslide deposits are present on the surface soils.

Five geological units are present at the Berkeley Lab: The Moraga and Orinda formations of the Contra Costa Group, the Great Valley Group, San Pablo Group, and the Claremont Formation of the Monterey Group. The Moraga Formation constitutes the main water-bearing unit at the Berkeley Lab. It consists mainly of lava flows, flow breccias, and agglomerates. The lava flows are typically highly fractured, jointed, or brecciated (broken up), creating a hydraulic conductivity that ranges between $10^{-2}$ to $10^{-4}$

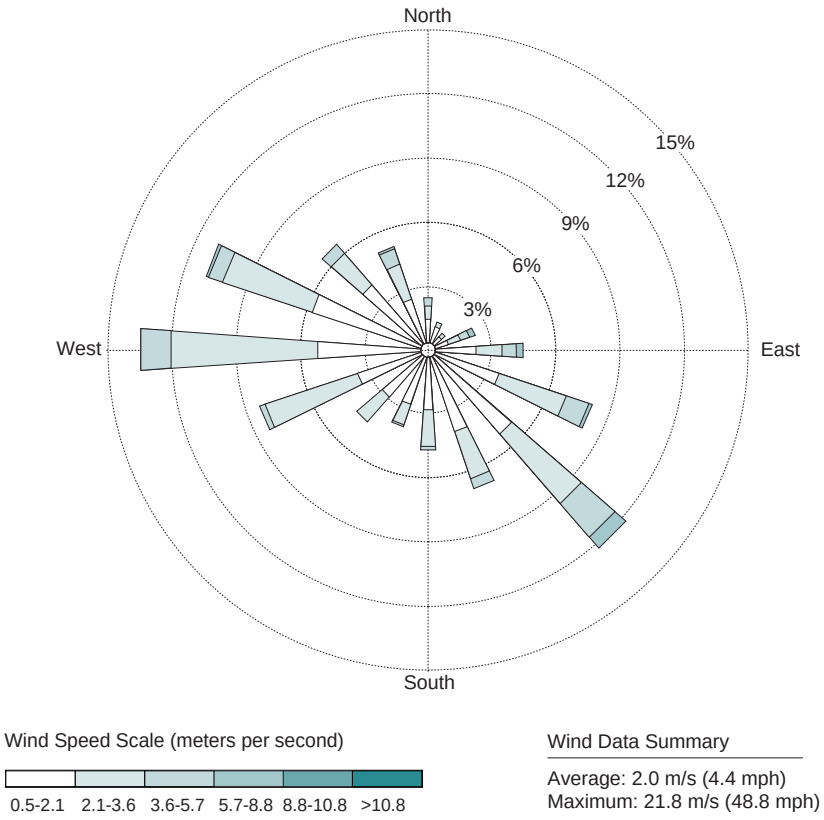


**Figure 4. Annual Wind Pattern for the Berkeley Lab**

centimeters per second. The presence of low permeability interbeds of clay and other sediments, as well as less fractured zones within this formation, create perched water conditions in some locations. The permeable Moraga Formation within the Lab is generally confined (both vertically and horizontally) with a very low permeability Orinda Formation that significantly impedes the movement of groundwater to the south and west. Across the site, water-table depths vary from less than 10 feet to more than 90 feet. A year-round spring occurs near Building 71.

### 2.3.3 Surface Water

The Berkeley Lab lies within the Strawberry Creek drainage basin, which is divided into the Blackberry Canyon and Strawberry Canyon watersheds. The North Fork of Strawberry Creek drains the Blackberry Canyon watershed at the northwest portion of the Lab. Several small creeks carry runoff from the rest of the Lab southward and join up with Strawberry Creek, which flows in a culvert from east to west, south of the southern boundary of the Lab. Both the North Fork and main branch of Strawberry Creek are perennial streams fed by springs, slope stability well discharges during the dry season, and hydraugers that have been installed to dewater and stabilize hillsides in the area around the Berkeley Lab complex (EPA 1998a). Chicken Creek also is a perennial

tributary of Strawberry Creek (Charbonneau 1987), with much of its flow likely from hydraugers (EPA 1998, Charbonneau 1987). The remaining tributaries from the area are more dependent on rainfall and typically are dry during the summer (EPA 1998a). Flow following storm events is dependent upon the amount and frequency of precipitation received; post-storm flow can last from days to weeks. The North Fork discharges into a 60-inch culvert just west of the Berkeley Lab boundary and emerges as a surface stream on the University campus. Strawberry Creek is diverted underground through a culvert and later emerges as a surface water stream near the eastern side of the campus. It joins the North Fork at the western side of the campus, shortly before it again goes underground and is routed to a City of Berkeley storm drain culvert. The storm drain carries runoff nearly three miles before discharging into San Francisco Bay. Prior to that, the creek surfaces for about 200 feet in Strawberry Park, a municipal park located about 1.75 miles west of the Lab (EPA 1998a).

Urbanization of the watershed has degraded the overall quality of Strawberry Creek and its tributaries. A significant increase in the amount of impervious surface areas in the watershed, along with extensive channel alteration and confinement, has altered the creeks' hydrologic regime. This had resulted in accelerated streambed degradation, bank erosion, and destruction of aquatic habitat (Charbonneau 1987). In 1987, UC Berkeley began an innovative program to restore the health of the creek. The Strawberry Creek Restoration Program has improved water quality markedly in the subsequent decade and a half.

### 2.3.4 Biological Resources

The majority of the vegetation within the site is located around the periphery, away from the centrally developed portion. Vegetation can be broadly categorized into four types: native woodland, eucalyptus plantations, a hillside habitat of grasses and brush, and mixed introduced species (which include ornamental plantings near buildings). Only the limited remnant stands of oak-bay woodland consist of species native to the site. The most common and widespread vegetation types on the Berkeley Lab site are the hillside habitat, the eucalyptus plantations, and mixed introduced species. The open grassy slopes of the hillside habitat occur primarily in the eastern portion of the Laboratory, while the western portion of the site is more heavily forested.

In general, the site supports habitats and associated wildlife that are typical of disturbed portions of the Berkeley-Oakland hills. An estimated 79 bird species, 20 mammal species, and 19 reptile and amphibian species occur on or near the site. A portion of the site is within a 407,000-acre zone designated by the U.S. Fish and Wildlife Service as a critical habitat for the Alameda whipsnake, which has been designated as "endangered." However, no Alameda whipsnake sightings have been reported on Berkeley Lab property. The most significant wildlife habitats at the site occur in lower Blackberry Canyon. This area supports relatively intact oak-bay woodland, but is completely surrounded by development, so provides only a small and limited habitat.

Aquatic life is expected to be limited in the Strawberry Creek and North Fork tributaries, given the highly variable flow in these waters along with scoured beds and eroded banks. Hardier fish species, such as roach, suckers and three-spined stickleback, have become established in the creek downstream from the Berkeley Lab on the UC Berkeley campus since the onset of restoration efforts in 1987 (University of California at Berkeley, 2000).

## 2.4 Physical and Chemical Properties of Tritium

Tritium is a radioactive isotope of hydrogen with an atomic number of 1 and an atomic weight of 3. It decays with emission of an electron to form $^{3}$He:

$$^{3}H \rightarrow {}^{3}He + e^{-}$$

The electron (beta particle) has a maximum energy of 18 keV and an average energy of 5.7keV (NCRP 1979). This energy is insufficient for skin penetration. Thus, tritium does not present an external radiation risk.

The physical and chemical characteristics of tritium are almost the same as hydrogen (Murphy 1993). Tritium gas may be oxidized in the environment and also burns in oxygen to form tritiated water (HTO), which is the principal form of tritium in the environment (NCRP 1979). Tritium also exchanges with hydrogen atoms of organic compounds to create organically bound tritium (OBT).

## 2.5 Tritium Sources

Tritium is stored at the NTLF chemically bound to a uranium bed that is under vacuum and contained in a sealed metal container. At the NTLF, the uranium bed cylinders are attached to a closed system inside a ventilated glove box. The cylinders are heated to release the chemically bound tritium from the uranium. All labeling reactions take place in the closed system within the glove box.

Tritium from fugitive losses in air that is drawn through the glove box ventilation system and the gaseous residual of tritiated water that is not trapped by the recovery system are directed through silica-gel traps and then to a stack on the hillside west of Building 75. A smaller amount is released from activities conducted in lab hoods and is vented to another stack located on the roof of the building (the Room 107 stack). Small quantities of tritium are emitted from the ventilation stack to the environment. Tritium releases are in the form of tritiated water vapor (HTO), and tritium gas (HT). HTO is the principal form of tritium released from the NTLF.

Tritium also is present naturally in the environment due to cosmic ray reactions in the upper atmosphere, and to a minor extent from neutron capture reactions of $^{6}$Li in rocks (Okada and Momoshima 1993). Tritium also is released from nuclear bomb detonations and from nuclear facilities such as nuclear power stations, nuclear fuel reprocessing

plants, and tritium production plants (NCRP 1979). A small amount of tritium is also contained in certain consumer products, such as self-luminous lights found in exit signs (Okada and Momoshima 1993).

## 2.6 Routine Environmental Monitoring[3]

Environmental monitoring is conducted regularly at the Berkeley Lab as part of the Lab's overall environmental compliance program. Both radiological and nonradiological contaminants are monitored. Air, soil/sediment, surface water, wastewater, groundwater, and vegetation are monitored on a regular basis.

A significant portion of the environmental monitoring program at the Berkeley Lab measures radiological impacts from Laboratory activities. The Laboratory monitors two types of radiation: (1) penetrating radiation from sources such as accelerators and (2) dispersible radionuclides from a wide range of Laboratory research activities. Specially designed shielding blocks are in place to reduce the release of penetrating radiation into the environment, and capture systems are used to minimize releases of dispersible radionuclides to the atmosphere. Discharges to the sanitary sewer are minimized by administrative controls.

The primary radiological compliance standards affecting the Laboratory are based on the maximum potential dose that a member of the public would receive from both direct penetrating radiation and dispersible radionuclides from the site. For the year 2000, this maximum annual dose to an individual was determined to be 0.3 millirem (mrem) (0.003 millisievert (mSv)) or only about 0.3% of the applicable DOE radiological standard of 100 mrem/yr (1 mSv/yr). This estimate is also about 0.1% of the naturally occurring background radiation in the San Francisco Bay Area, which is 260 mrem/yr (2.6 mSv). Thus, Berkeley Lab is a minor contributor to the dose received by a typical member of the public from all contributing sources of radiation (i.e., natural terrestrial background, medical, and consumer products).

EPA regulates dispersible radionuclide emission sources. EPA has set 10 mrem/yr (0.10 mSv/yr) as the maximum allowable dose to the public from all exposure pathways (i.e., inhalation, ingestion, and immersion) resulting from airborne releases of radionuclides from a site. The estimated maximum potential dose from all dispersible airborne radionuclides released from the Laboratory site in 2000 was about 0.1 mrem (0.001 mSv), with tritium accounting for about 64% of that amount. This dose is about 30% of Berkeley Lab's total maximum dose to the public for both penetrating radiation and dispersible radionuclides.

3. The majority of information presented in this section is taken directly from the Site Environmental Report for 2000. See http://www.lbl.gov/ehs/epg/00ser/ for a complete report.

The Berkeley Lab's airborne tritium monitoring program supplements compliance activities conducted in accordance with the EPA National Emission Standards for Hazardous Air Pollutants (NESHAPs) requirements. Under NESHAPs, the Berkeley Lab is required to perform an annual assessment of radioactive air emissions from operations at the site. These emissions are input to EPA's CAP88-PC air dispersion model, which is used to calculate the radiological dose from stack emissions at the location of a hypothetical maximally exposed individual. The results of these assessments show that the facility has been in compliance with the NESHAPs dose standard of 10 mrem (0.10 mSv) per year since the standard was implemented in 1990. The NESHAPs dose standard is considered to be an Applicable or Relevant and Appropriate Requirement (ARAR) in Superfund.

Since 1990, the air-monitoring program has collected over 1,000 stack and ambient air samples. In addition, Berkeley Lab collects onsite meteorological data to assist in evaluating the tritium monitoring results. The stack air monitoring data has shown that average tritium emissions have declined by a factor of 10 since 1990. Four monitoring stations have consistently reported no detectable levels of tritium since 1999, and there are no residences within the zone of detectable concentrations.

Historically more than 100 surface water samples, 100 soil or sediment samples, and 1,000 groundwater samples have been obtained and analyzed for tritium. The tritium concentrations in the soil samples have all been well below health-based soil screening levels. Surface water samples have all been well below the tritium drinking water standard. Tritium was detected in 18 of 60 groundwater wells at an average concentration well below the drinking water standard. The Berkeley Lab has also sampled media that are not used by EPA in Superfund investigations, particularly urine and vegetation.

As required by the wastewater discharge permits issued to the Laboratory by EBMUD, Berkeley Lab samples for radionuclides, as well as nonradionuclide parameters, in sanitary sewer discharges. All results in 2000 were well within compliance limits.

Berkeley Lab has conducted extensive groundwater monitoring since the early 1990s, and nine groundwater plumes have been identified, including one tritium plume. These plumes are all on-site. The groundwater in the vicinity of the Laboratory is not used as a public drinking water source (EPA 1998a). The Laboratory has nearly completed characterizing these plumes and is developing long-term strategies to address the contamination under the RCRA corrective actions process. Until the Laboratory can implement these strategies, it has initiated several interim corrective action measures to remediate the contaminated media or prevent movement of contamination. Concentrations of contaminants are reported to regulatory agencies quarterly, along with other program developments and planned activities.

The soil and sediment compliance-monitoring program analyzes samples for radionuclides (including tritium), metals, pH, and organic compounds at locations that complement sampling in other media such as air and surface water. Results reported for 2000 were generally below or near analytical detection limits, and in no instances exceeded regulatory limits.

## 2.7 Supplemental Sampling Program

In addition to these routine programs, the Berkeley Lab began conducting supplemental sampling in 2001 of ambient air, soil, sediment, surface water and vegetation to satisfy EPA and stakeholder groups' requests for additional environmental tritium data. The supplemental sampling program is scheduled to continue until May 2002.

The sampling program followed EPA's data quality objective process (EPA 1998c). The primary purpose of the supplemental environmental investigations is to collect data of the appropriate type and quality for EPA to decide whether to place the Berkeley Lab on the NPL. Consequently, a sampling program was designed to meet all the objectives of the HRS scoring system used by EPA to support listing decisions. Samples were collected from areas historically shown to be maximum concentration areas and from areas more distant from the NTLF, where concentrations would be expected to be less, but where potential receptors (targets) exist. Samples were collected from all target distances and locations needed to complete the HRS. The targets for the air pathway were considered to be people living or working within 1 mile of the NTLF. The targets for the soil pathway were residents, workers and students on and near the NTLF. The targets for the surface water pathway were fish and wildlife in San Francisco Bay. A tiered sampling plan was designed. Additional samples were to be collected if the initial samples (tier one) exceeded a specified health-protective concentration benchmark. None of the tier one samples exceeded these benchmarks, and therefore no tier two sampling was needed. All data were validated in accordance with EPA's Superfund data validation requirements.

The NTLF continued to conduct routine operations during the initial months of the supplemental sampling period. Labeling experiments performed during the sampling period typically were preceded by preparation activities, and followed by hardware and glove box atmosphere cleanup procedures. Many of those related activities resulted in small HTO emissions through the Hillside or Room 107 stacks. From March 28$^{th}$ to August 15$^{th}$, HTO emissions from the NTLF totaled 4.9 curies, based on continuous stack monitoring data collected by the Lab as part of routine operations. This equates to approximately 13 curies on an annual basis. By comparison, in year 2000, NTLF stack HTO emissions totaled 21 curies.

The scope and results of this supplemental sampling program for ambient air, soil, sediment, and surface water are summarized below. Vegetation data are not presented, as

these were not requested by EPA. The sampling plan documents (LBNL 2001a-d) provide a complete description of these activities.

### 2.7.1 Air Program

Ambient air samples were collected continuously from 15 monitoring sites surrounding the NTLF facility. Seven of these locations are part of the historical air monitoring network established for routine compliance monitoring. Another six locations were added to the compliance monitoring network in the spring of 2001 to provide better sampling coverage of all wind directions from the NTLF. Two additional locations were added for the supplemental sampling to address the EPA request for additional resolution of tritium levels in ambient air in the primary wind direction downwind of the NTLF (ENV-UCBG), and at a background location (ENV-AR) similar in elevation and weather conditions, but significantly further (1.4 miles) from the NTLF. Figure 5 depicts the sampling locations in relation to the NTLF. Under the plan, supplemental ambient air sampling will continue until May of 2002. The air samples considered in this report were collected from early May through early August of 2001. A total of 69 air samples were collected during the three-month period. This included 45 primary samples and 24 split samples from various sites in the network. HTO emissions from the NTLF during the air-sampling period totaled about 3.5 curies.

The Berkeley Lab environmental monitoring program samples ambient air for tritium (in the form of tritiated water (HTO)) by pumping air at a constant rate through a column of dry silica gel. Volumetric sample air flows are recorded, and the silica gel columns are changed monthly. The collected silica gel samples are split into approximately equal portions, and one portion is sent to a laboratory for HTO analysis. The analytical reporting limit was in the range of 2 to 5 $pCi/m^3$.

To address quality control during the supplemental sampling, at least 10 percent of the split samples were sent to a commercial analytical laboratory and Lawrence Livermore National Laboratory for HTO analysis. Additionally, at least another 10% of the split samples were provided to EPA for its analysis.

HTO was detected in 52 of 69 individual samples (including split samples) analyzed during the sampling period. Table 1 summarizes minimum and maximum concentrations at each sampled location. Tritium levels were greatest in the immediate area around the Building 75 Hillside Stack, often in the predominant wind direction for night-time and storm winds (to the north-west) or for daytime winds (to the east), confirming trends observed during previous monitoring (LBNL 2001c). The highest concentrations were detected at ENV-75EG, located approximately 65 feet north-northwest of the stack, in a eucalyptus tree grove that surrounds the stack. There are no human receptors located in this area. Previous monitoring data collected by the Berkeley Lab also reported the highest ambient air tritium concentrations at this location (LBNL 2001c). Two of the next three highest concentrations (ENV-78 and ENV-77), though not in a predominant



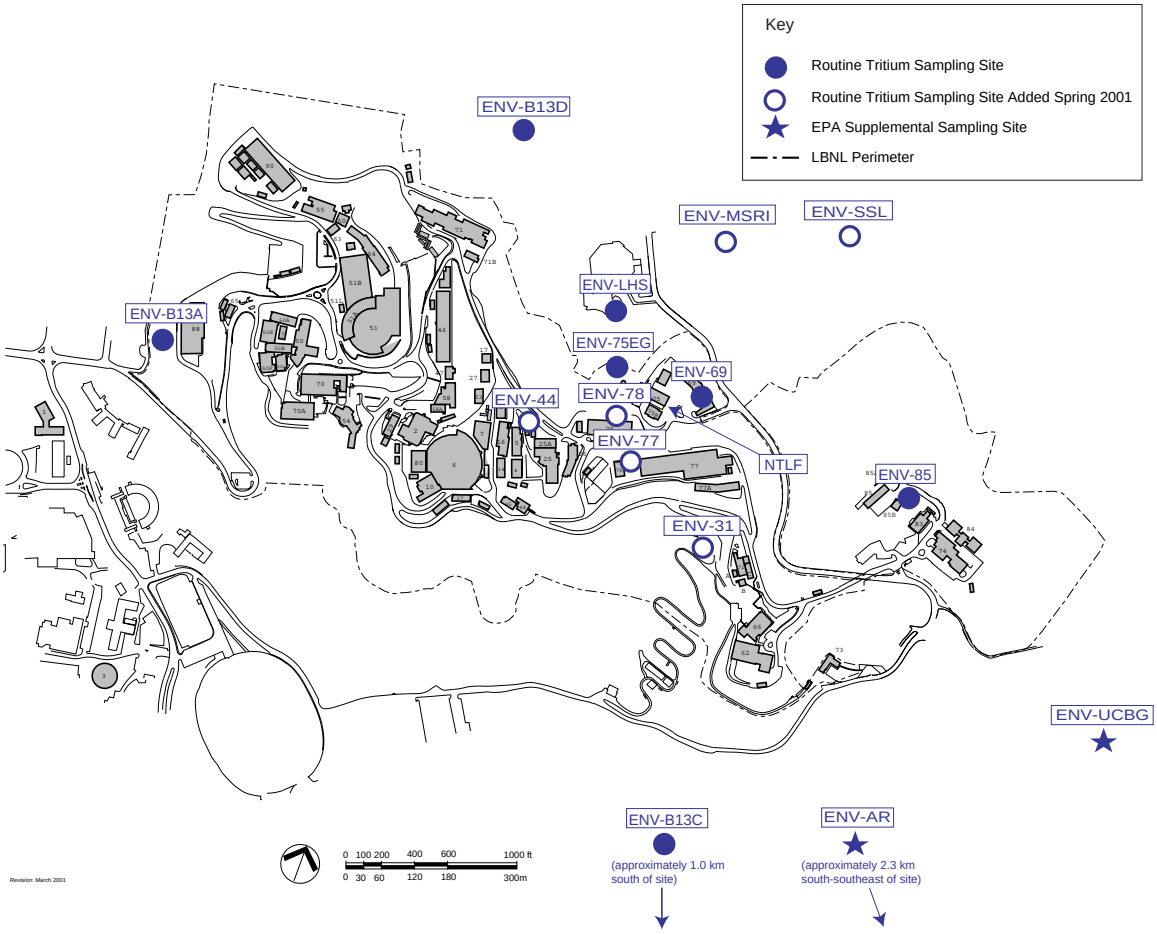


**Figure 5. Air Monitoring Stations for 2001 Supplemental Sampling**

wind direction, were collected from locations among the closest to the Hillside Stack Higher concentrations also were reported at ENV-69, located 450 feet east of the stack, and at ENV-LHS, located 400 feet to the north-northwest. All of the ambient air tritium concentrations were below the EPA NESHAP concentration limit for ambient air of 1,500 pCi/$M^3$.

Three sampling stations are located in residential areas: ENV-B13A, ENV-B13C, and ENV-B13D. Maximum concentrations at these locations ranged from 3.2 pCi/$m^3$ to 8.6 pCi/$m^3$. The maximum concentration at the background location (ENV-AR) was 6.4 pCi/$m^3$. Maximum concentrations at the remaining sample locations were in the range of 3 to14 pCi/$m^3$.

Overall, the supplemental sampling data support the historically reported trends of maximum concentrations near the stack, commonly in the predominant wind directions. Concentrations at more distant locations are substantially lower and, in many cases, at or near background levels for the region.

**Table 1. Air Monitoring Data Summary**

| Sampling Location | Tritium Concentration (pCi/m$^3$) | |
|---|---|---|
| | Minimum[1] | Maximum [2] |
| ENV-75EG | 34.9 | 119.3 |
| ENV-78 | 10.8 | 76.5 |
| ENV-77 | 5.90 | 52.7 |
| ENV-LHS | 12.1 | 41.3 |
| ENV-69 | 10.7 | 18.4 |
| ENV-MSRI | 8.15 | 14.0 |
| ENV-44 | 4.20 | 13.7 |
| ENV-SSL | 8.20 | 13.7 |
| [3] ENV-B13C | 8.40 | 8.60 |
| ENV-UCBG | 4.20 | 7.71 |
| [4] ENV-AR | 2.36 | 6.41 |
| ENV-31 | 4.49 | 4.49 |
| [3] ENV-B13D | 4.40 | 4.40 |
| ENV-85 | 2.49 | 3.60 |
| [3] ENV-B13A | 3.20 | 3.20 |

[1] Value reported across all sample periods. Minimum detected value. Detection limits ranged from < 4 to < 5 pCi/m3 in non-detected samples.

[2] Value reported across all sample periods.

[3] Residential area

[4] Background location.

### 2.7.2. Soil Program

Soil samples were collected from 64 locations up to a maximum distance of approximately 2000 feet from the NTLF Hillside Stack. The locations were selected to provide sample coverage in a radial pattern around the Hillside Stack. Two additional locations (SSNTLF-01-65 and SSNTLF-01-66), situated approximately 1 mile northeast of the NTLF, were sampled to represent background conditions in the area. Samples were collected from 0.5 to 1 feet below ground surface and 1.5 to 2 feet below ground surface. The top 6 inches of surface material was removed prior to sampling to ensure that non-soil material (e.g., grass, leaves) was excluded from the soil sample. A total of 208 samples was analyzed, including all split and duplicate samples across all depths. The soil samples were collected from early April to early May. HTO emissions during that period totaled approximately 1.5 curies.

Figures 6, 7, and 8 identify the soil sampling locations.

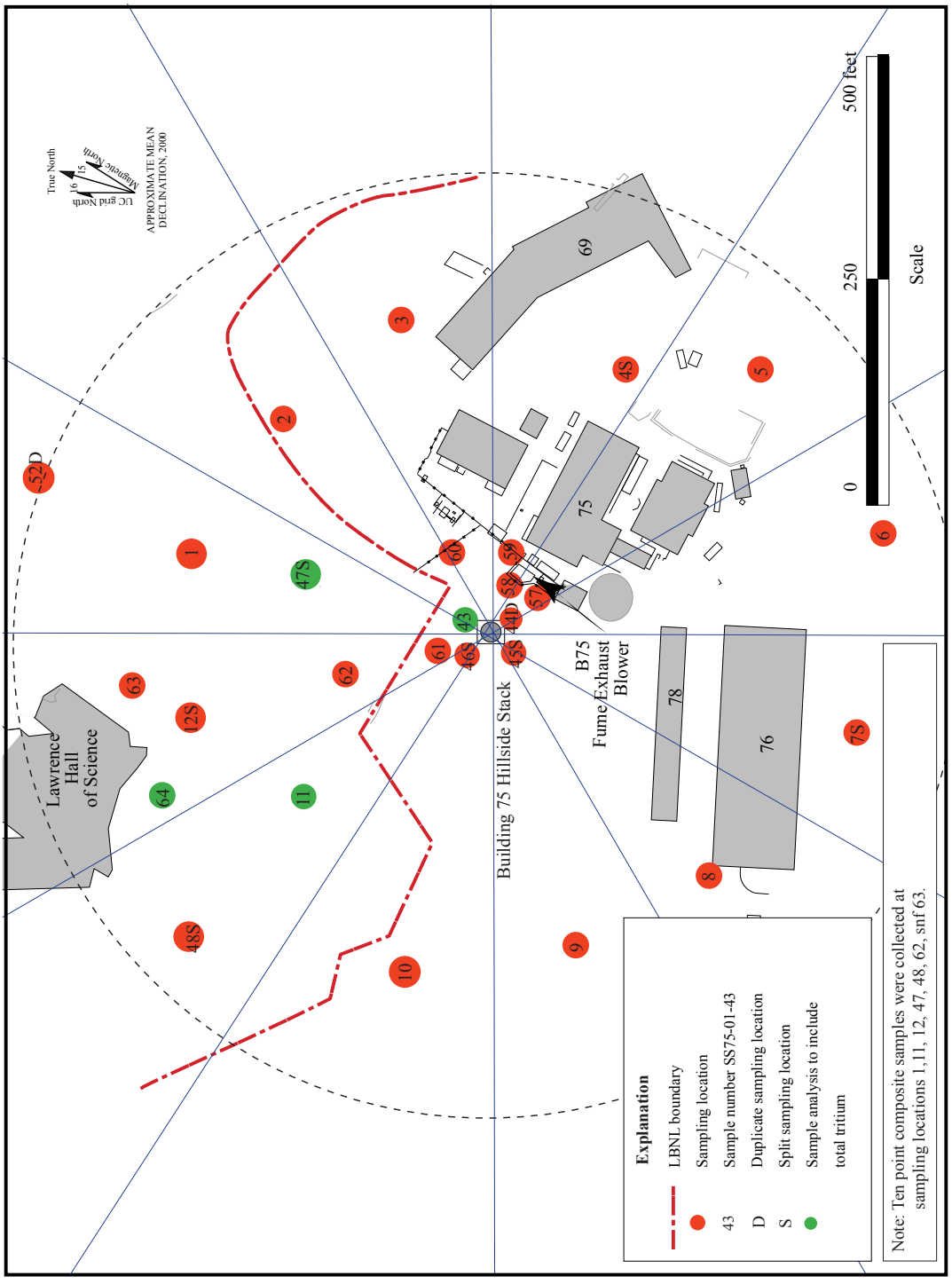


**Figure 6. Supplemental Soil Sample Locations Near the NTLF Hillside Stack**

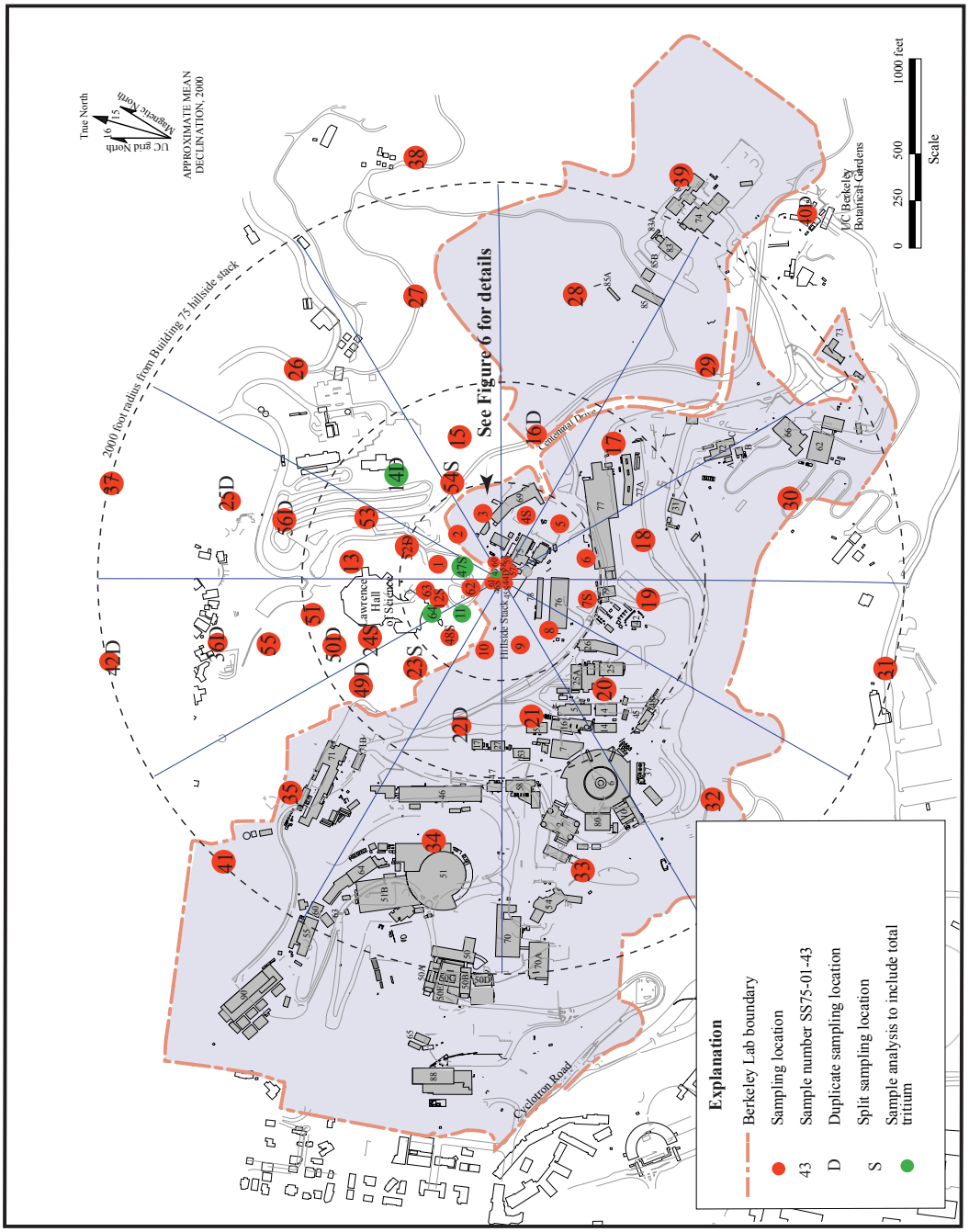


**Figure 7. Supplemental Soil Sample Locations on and around Berkeley Lab**

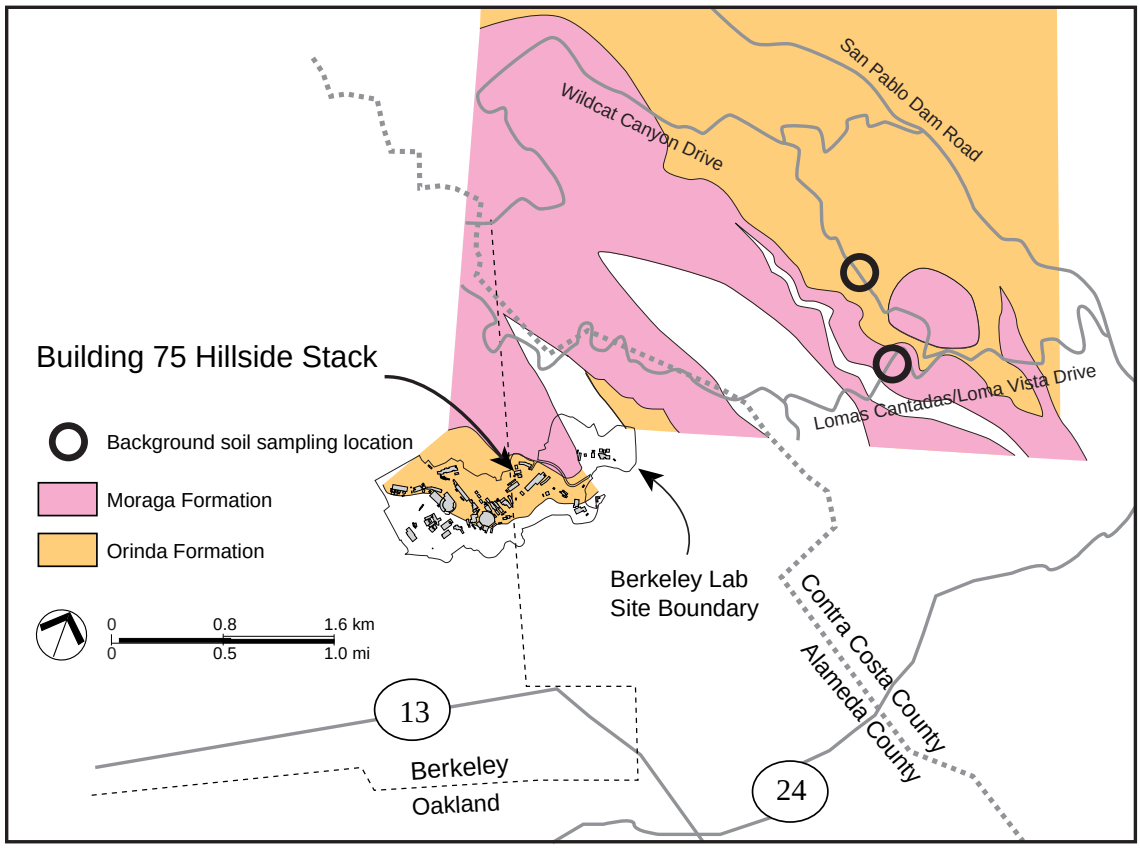


**Figure 8. Supplemental Soil Sample Background Locations**

Samples were collected using a soil drive sampler loaded with a 6-inch-long brass liner to collect the sample. Single point (discrete) samples were collected at all locations. In addition, composite soil samples were collected from six locations to address concerns expressed by the City of Berkeley. Duplicate samples were collected at approximately 20% of the locations. Split samples were collected at approximately 15% of the locations and sent to EPA and a third analytical laboratory for analysis.

Samples were analyzed for HTO. In addition, samples from 5 locations where soil tritium levels were historically highest were analyzed for total tritium (HTO and organically bound tritium (OBT)). The detection limit for all HTO analyses was 0.2 pCi/g; the detection limit for total tritium was 5 pCi/g.

Tritium was detected at 21 of 66 locations and 66 of 208 sample results overall. The highest concentration was reported at location SSNTLF-01-43, collected immediately adjacent to the Building 75 Hillside Stack. Of the 5 locations with detected concentrations greater than 1 pCi/g, 4 of these were located very close to the stack. The other location (SSNTLF-01-62) was located within 200 feet of the stack, to the north. All

of the 21 locations at which tritium was detected were within 500 feet of the stack. Tritium was not detected at either background location or in samples collected from nearby residential locations (SSNTLF-01-36, 42). See Table 2.

Concentrations of total tritium were between 4 and 5 times greater than HTO at location SSNTLF-01-43. Total tritium was not detected at other locations, with a detection limit of 5 pCi/g, even though HTO was reported at the majority of these locations. It is possible that OBT tritium is present at these locations, and that the difference in detection limits between HTO and total tritium masks this information. If OBT tritium is present at these other locations, however, it is below 5 pCi/g. Table 3 summarizes the results of total tritium and corresponding HTO analyses.

Overall, the soil sampling data indicate that the distribution of tritium in soils is limited to areas adjacent to or near the NTLF Hillside Stack. These findings are consistent with historical sampling results (LBNL 2001a), and consistent with the ambient air monitoring data that indicate highest concentrations nearest the source.

### 2.7.3 Sediment Sampling Program

Twenty-six sediment samples were collected from nine creeks within or near the Berkeley Lab site (Figure 9). In addition, background sediment samples were collected from Lake Anza and Lake Temescal, located between one and two miles north and south, respectively, of the Berkeley Lab (Figure 10).

Samples were collected from the top six inches of sediment using the same methods as described for soil. Duplicate samples were collected at approximately 20% of the locations. Split samples were collected at approximately 10% of locations and sent to EPA and a third analytical laboratory for analysis.

All samples were analyzed for HTO; five samples were also analyzed for total tritium. Detection limits were 0.2 pCi/g for HTO and 5 pCi/g for total tritium.

Tritium was detected in only a single sample, from Banana Creek. The reported value was at the detection limit of 0.2 pCi/g. Tritium was not detected in the corresponding split sample. Given this, and the lack of tritium in any other sediment samples, the single reported detection in Banana Creek is suspect. In any event, the collective sediment data indicate that tritium is not distributed in sediments of area creeks. Tritium was not detected in the background samples.

### 2.7.4 Surface Water Sampling Program

Surface water samples were collected from the same locations as sediment samples (Figure 9), in glass bottles. Background samples also were collected from Lake Anza and

## Table 2. Soil Monitoring Data Summary

| Sampling Location | Tritium Concentration (pCi/g) | | Sampling Location | Tritium Concentration (pCi/g) | |
|---|---|---|---|---|---|
| | Minimum [1] | Maximum [2] | | Minimum [1] | Maximum [2] |
| [3] SSNTLF-01-43 | 41.2 | 41.4 | SSNTLF-01-15 | ND | ND |
| [4] SSNTLF-01-65 | ND | ND | SSNTLF-01-16 | ND | ND |
| [4] SSNTLF-01-66 | ND | ND | SSNTLF-01-17 | ND | ND |
| [5] SSNTLF-01-36 | ND | ND | SSNTLF-01-18 | ND | ND |
| [5] SSNTLF-01-42 | ND | ND | SSNTLF-01-19 | ND | ND |
| [5] SSNTLF-01-55 | ND | ND | SSNTLF-01-20 | ND | ND |
| SSNTLF-01-46 | 3.53 | 4.42 | SSNTLF-01-21 | ND | ND |
| SSNTLF-01-61 | 1.86 | 2.84 | SSNTLF-01-22 | ND | ND |
| SSNTLF-01-62 | 1.67 | 2.18 | SSNTLF-01-23 | ND | ND |
| SSNTLF-01-59 | 1.06 | 1.3 | SSNTLF-01-24 | ND | ND |
| SSNTLF-01-60 | 0.746 | 0.977 | SSNTLF-01-25 | ND | ND |
| SSNTLF-01-12 | 0.67 | 0.957 | SSNTLF-01-26 | ND | ND |
| SSNTLF-01-47 | 0.5752 | 0.935 | SSNTLF-01-27 | ND | ND |
| SSNTLF-01-63 | 0.54 | 0.696 | SSNTLF-01-28 | ND | ND |
| SSNTLF-01-45 | 0.24 | 0.608 | SSNTLF-01-29 | ND | ND |
| SSNTLF-01-01 | 0.289 | 0.542 | SSNTLF-01-30 | ND | ND |
| SSNTLF-01-11 | 0.298 | 0.542 | SSNTLF-01-31 | ND | ND |
| SSNTLF-01-44 | 0.261 | 0.405 | SSNTLF-01-32 | ND | ND |
| SSNTLF-01-57 | 0.341 | 0.347 | SSNTLF-01-33 | ND | ND |
| SSNTLF-01-04 | 0.3 | 0.3 | SSNTLF-01-34 | ND | ND |
| SSNTLF-01-64 | 0.296 | 0.297 | SSNTLF-01-35 | ND | ND |
| SSNTLF-01-48 | 0.221 | 0.283 | SSNTLF-01-37 | ND | ND |
| SSNTLF-01-07 | 0.28 | 0.28 | SSNTLF-01-38 | ND | ND |
| SSNTLF-01-58 | 0.276 | 0.276 | SSNTLF-01-39 | ND | ND |
| SSNTLF-01-10 | 0.237 | 0.237 | SSNTLF-01-40 | ND | ND |
| SSNTLF-01-02 | 0.2 | 0.2 | SSNTLF-01-41 | ND | ND |
| SSNTLF-01-03 | ND | ND | SSNTLF-01-49 | ND | ND |
| SSNTLF-01-05 | ND | ND | SSNTLF-01-50 | ND | ND |
| SSNTLF-01-06 | ND | ND | SSNTLF-01-51 | ND | ND |
| SSNTLF-01-08 | ND | ND | SSNTLF-01-52 | ND | ND |
| SSNTLF-01-09 | ND | ND | SSNTLF-01-53 | ND | ND |
| SSNTLF-01-13 | ND | ND | SSNTLF-01-54 | ND | ND |
| SSNTLF-01-14 | ND | ND | SSNTLF-01-56 | ND | ND |

ND: Not detected. Detection limits ranged from < 0.2 pCi/g for HTO to <5 pCi/g for total tritium.

[1] Minimum detected value reported across all duplicates and sample depths.

[2] Maximum detected value reported across all duplicates and sample depths.

[3] Values are for total tritium.

[4] Background location.

[5] Residential area.

**Table 3. Comparison of Soil HTO and Total Tritium Results**

| Sampling Location | Sample Depth | Maximum Tritium Concentration (pCi/g) | |
|---|---|---|---|
| | | HTO | Total Tritium |
| SSNTLF-01-11 | 0.5 - 1.0 ft | 0.389 | < 5 |
| | 0.5 - 1.0 ft [C] | 0.542 | < 5 |
| | 1.5 - 2.0 ft | 0.298 | < 5 |
| | 1.5 - 2.0 ft [C] | 0.378 | < 5 |
| SSNTLF-01-14 | 0.5 - 1.0 ft | < 0.2 | < 5 |
| | 0.5 - 1.0 ft [D] | < 0.2 | < 5 |
| | 1.5 - 2.0 ft | < 0.2 | < 5 |
| | 1.5 - 2.0 ft [D] | < 0.2 | < 5 |
| SSNTLF-01-43 | 0.5 - 1.0 ft | 7.86 | 41.4 |
| | 1.5 - 2.0 ft | 9.98 | 41.2 |
| SSNTLF-01-47 | 0.5 - 1.0 ft [C,S] | 0.5752 | < 5 |
| | 0.5 - 1.0 ft [C] | 0.862 | < 5 |
| | 0.5 - 1.0 ft | 0.799 | < 5 |
| | 1.5 - 2.0 ft | 0.763 | < 5 |
| | 1.5 - 2.0 ft [C,S] | 0.6953 | < 5 |
| | 1.5 - 2.0 ft [C] | 0.935 | < 5 |
| SSNTLF-01-64 | 0.5 - 1.0 ft | 0.296 | < 5 |
| | 1.5 - 2.0 ft | 0.297 | < 5 |

[C] Composite sample.

[D] Duplicate samples.

[S] Split samples.

Lake Temescal (Figure 10). Duplicate and split samples were collected for approximately 20% and 10% of the locations, respectively. Samples were analyzed for HTO. The detection limit was 200 pCi/L.

Tritium was detected in surface water samples from upper and lower Chicken Creek sampling locations at concentrations ranging from 233 to 563 pCi/L. It was not detected in any other surface water sample, or in the background samples. Chicken Creek receives groundwater discharge from hydraugers installed on the Berkeley Lab property. Groundwater in the area contains tritium, and it is likely that the detected concentrations reflect groundwater discharge to the creek. Historical data document tritium concentrations in Chicken Creek above those in other creeks of the area (EPA 1998a).

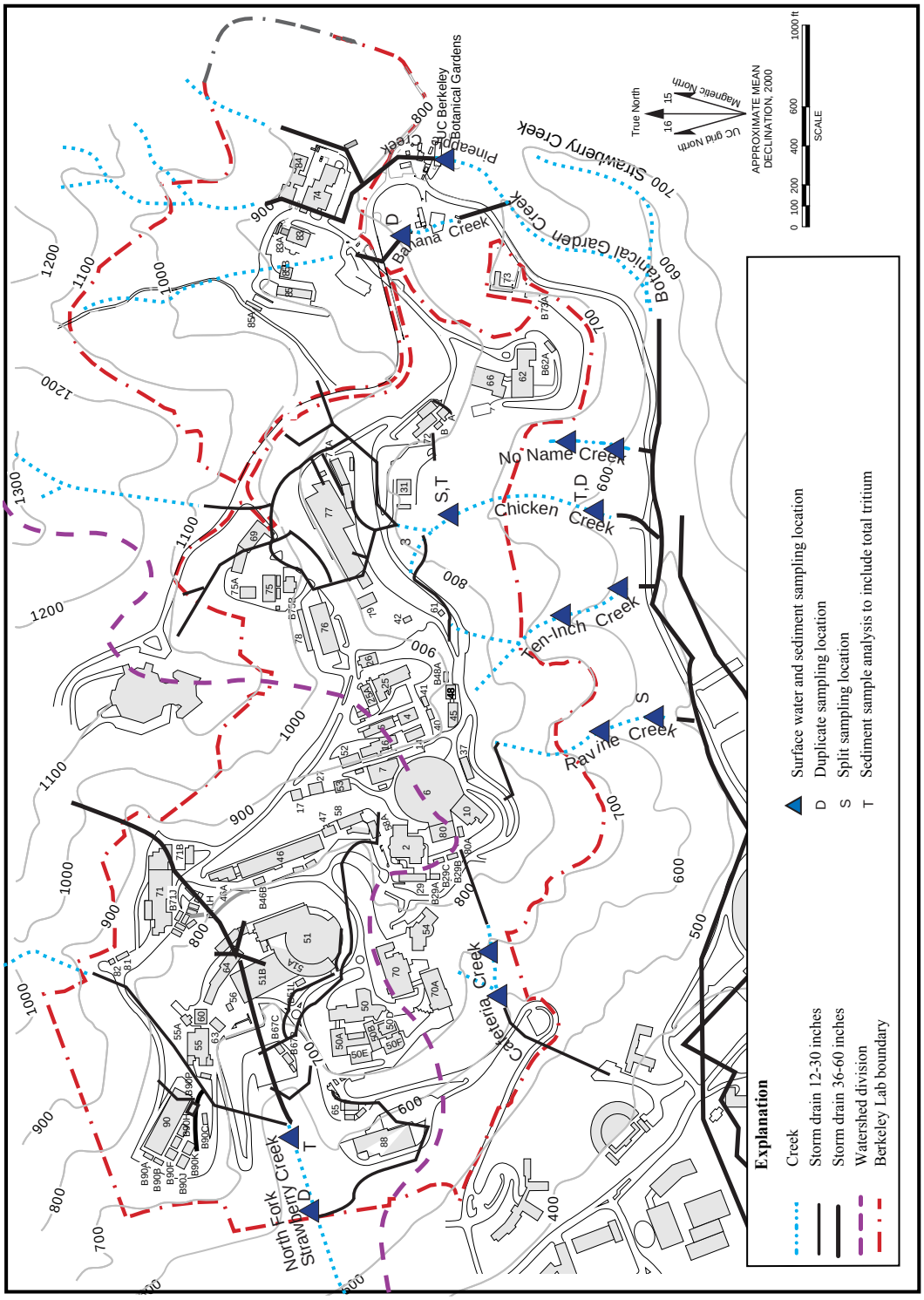


**Figure 9. Supplemental Surface Water and Sediment Sample Locations on and near the Berkeley Lab Site**

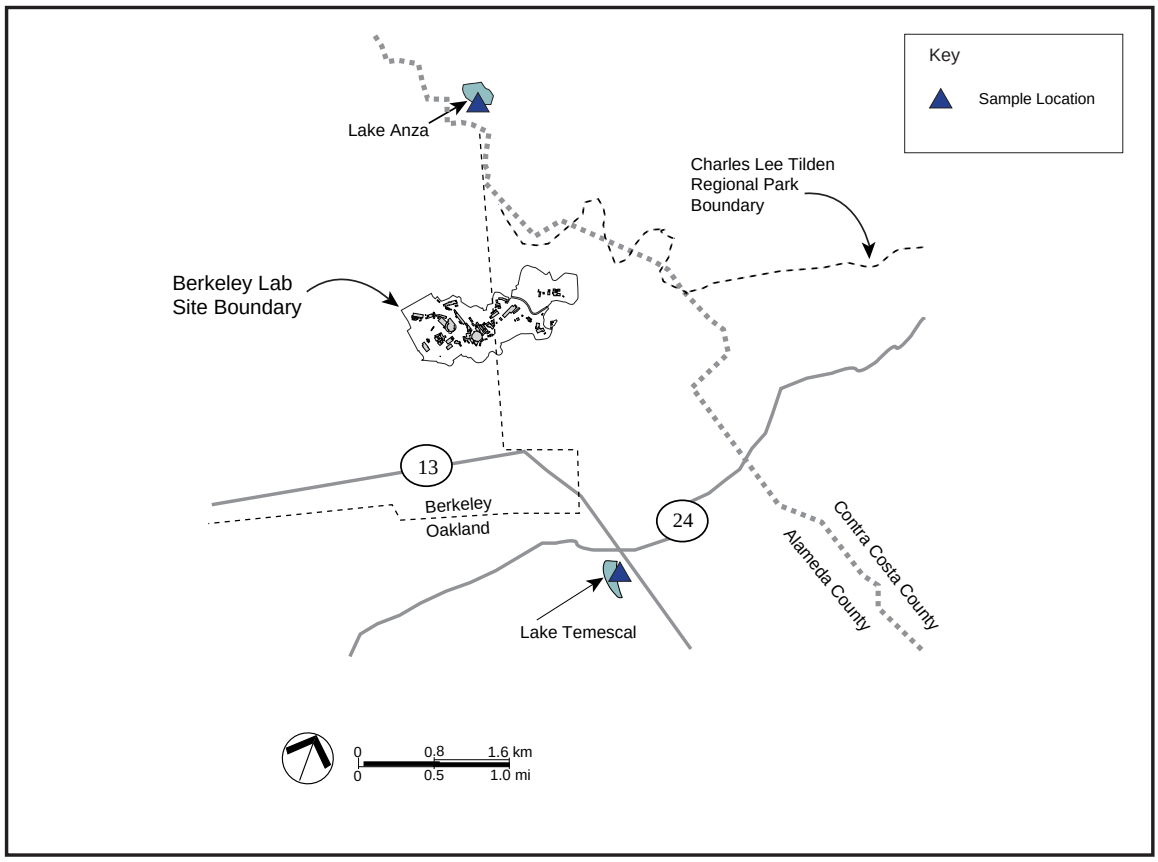


**Figure 10. Supplemental Surface Water and Sediment Sample Background Locations**

# 3.0 EXPOSURE ASSESSMENT

Exposure is defined as the contact of a receptor with a chemical or physical agent, and exposure assessment is the process by which the magnitude, frequency, duration, and route of contact is estimated (EPA 1989a). In this report, exposure assessment is conducted in two steps. First, the pathways by which receptor populations can become exposed to environmental tritium are identified, and pathways and populations are selected for more detailed evaluation. Then, exposure is quantified for each pathway and receptor combination. Exposure point concentrations are calculated for each selected receptor population and pathway combination, and tritium intake (as pCi) is calculated for the exposed individual. The methods and assumptions used to support the calculations are described.

## 3.1 Potential Exposure Pathways

Tritium is stored at the NTLF chemically bound to a uranium bed contained in a sealed metal container. During labeling activities, small amounts of tritium are released to ambient air via stacks vented from the roof of Building 75 and on a hillside west of the building. Most of the released tritium is in the form of HTO. There are several other minor sources of tritium at the Berkeley Lab, including the Donner Laboratory, Research Medicine & Radiation Biophysics and Biomedical Isotope Laboratory, Nuclear Science program laboratories, Hazardous Waste Handling Facility, and Molecular and Cell Biology laboratory. These sources combined, however, constitute less than 1% of the total annual tritium emissions from the Berkeley Lab and will not be considered further in this assessment.

In general, once tritium is released, it rapidly disperses in the environment. Dispersion and transport is typically directed by the predominant winds. Some portion of airborne tritium will deposit to the ground via wet deposition (i.e., precipitation). Some dry deposition of tritium also occurs, primarily by direct removal of atmospheric tritium at vegetative, soil, and water surfaces (Murphy 1993). Once on the ground surface, tritium can follow several transport paths. It can percolate into groundwater, be taken up by plant roots, be transported via surface run-off to nearby waters, or be re-released to the atmosphere either directly from the soil or from respiring plants (Murphy 1993, NCRP 1979). Tritium does not concentrate in biological systems, though it can be taken up to the same degree as water (NCRP 1979). Radioactive decay of tritium occurs concomitant with physical transport processes.

Monitoring data from the facility generally confirm these typical transport pathways. Tritium has been detected in ambient air samples, with the greatest concentrations near the NTLF stacks and/or in the predominant downwind direction. Tritium also has been detected in soils near the facility, indicating that some portion of the airborne tritium has been deposited to the ground. As with the air samples, soil concentrations are greatest

immediately adjacent to the facility, and no tritium was detected in soil samples located more than 500 feet from the stack. This suggests that most of deposition from the tritium emissions occurs close to the source. Tritium also has been detected in groundwater, indicating that some soil-associated tritium has percolated through the soil column along with infiltrating rainwater. There appears to be little overland transport of tritium from soils, as tritium was not detected in surface waters and sediments throughout the majority of the watershed. Tritium also has been detected in vegetation, with highest concentrations occurring within 150 feet of the stacks, and primarily non-detectable levels at locations 300 feet or more from the stack (LBNL 2001d).

People who live and work in the vicinity of the NTLF could be exposed to environmental tritium via a number of routes. External radiation exposure is not of concern for tritium because the beta particles released during tritium decay cannot penetrate the outer layer of skin (ICRP 1983). Furthermore, EPA has not developed risk factors for the external exposure route (EPA 2000b, 1999b).

## Air

Workers and nearby residents can be exposed to airborne HTO directly via inhalation. In addition, HTO in air can enter the body by dermal uptake of water vapor. Both of these exposure routes will be evaluated in this assessment. HTO in air also can be taken up along with other water vapor in locally grown produce and be ingested by residents. This pathway does not contribute significantly to overall risks, however (McKone et al. 1997), and will not be quantified. A qualitative discussion is included in the risk characterization section.

## Soil

The potential for soil exposure depends on the accessibility of the surface soil and the activity patterns of the potential receptor populations. In general, people could be exposed to tritium in soil directly via inadvertent ingestion of soil that contacts the hands or other part of the body, via inhalation of fugitive dusts that are generated during earth moving activities (e.g., digging, grading), or via ingestion of home-grown produce that has been contaminated via plant uptake[4]. Off-site residents could be exposed via each of the identified pathways, but tritium was not detected in soils from any residential sampling location. Construction or maintenance workers at the Berkeley Lab who might be involved in digging activities could be exposed via direct ingestion and inhalation of fugitive dust and are probably the most likely potentially exposed population on the Lab property. Soil exposure in other workers at the NTLF or in the remainder of the Berkeley Lab is less likely, since these workers are not routinely involved in activities that result in

4. Dermal absorption from soil is not an important exposure pathway for tritium and other radionuclides (EPA 2000a).

soil contact. Students or other visitors to the Lab could contact soil, but given that the Lab grounds are extensively vegetated or paved, this is considered unlikely.

EPA (2000a) has developed a soil screening procedure to help standardize and accelerate the evaluation and cleanup of soils contaminated with radioactive materials at sites on the NPL. As part of this guidance, EPA developed risk-based soil screening levels (SSLs) that can be used to identify areas of a site needing further investigation. SSLs are not clean-up levels and do not alone trigger the need for response actions. However, they can be used to identify areas and conditions at a particular site where no further federal attention is required. Generally, at sites where radionuclide concentrations fall below the SSL, no further action or study is warranted under the Superfund program (EPA 2000a).

The EPA SSLs are residential risk-based limits. Given that tritium was detected only adjacent to or near the NTLF in areas of potential worker exposure and not in any of the sampled residential locations, the SSLs are not strictly applicable for the soils data at the NTLF because worker exposures are less than residential exposures under standard EPA paradigms. However, the residential SSLs can be used to provide a conservative risk-based screen for soils data where worker exposures are possible.

EPA has developed SSLs for tritium to address potential exposures via direct ingestion of soil and inhalation of fugitive dust, which are the potential worker exposure pathways at the NTLF. The SSL for tritium for direct ingestion of soil is 8,580 pCi/g. The SSL for inhalation of fugitive dust is 323,000,000 pCi/g[5]. The maximum detected concentration of tritium in sampled soils was 41.4 pCi/g, or less than 0.5% of the lower of these residential SSLs. All other samples are 0.05% of this SSL. Detected soil concentrations are also 2-3 orders of magnitude below the EPA Region IX preliminary remediation goals (PRGs)[6] of 11,000 pCi/g for residential soil and 45,000 pCi/g for commercial/industrial soil. Based on this, it can be concluded that construction workers or other individuals exposed to tritium in site soils will not be at risk of adverse health effects.

EPA's tritium SSL was developed assuming that all tritium in soil is in the form of HTO. The maximum reported tritium value of 41.4 pCi/g was for total tritium, of which 7.86 pCi/g was HTO. The remaining tritium was organically bound tritium (OBT). The risk factor for OBT is two times higher than that for HTO (EPA 1999b). However, given the magnitude of degree to which site soil tritium levels fall below the tritium SSL, this uncertainty does not alter the conclusion that tritium in site soils does not pose a risk to people living or working in the area.

5. These are the SSLs uncorrected for decay. The decay-corrected SSLs are approximately a factor of 2 higher.
6. EPA (1998d).

## Surface Water

Tritium was detected in Chicken Creek but no other surface waters. Chicken Creek is not used recreationally by students or nearby residents. Access to the creek is difficult as its banks are very steep and consist of loose soil in many areas. Most of the banks are heavily vegetated also, further limiting access. In general, the creek is narrow and the streambed is rocky with very limited flow. In addition, a large portion of the streambed is within Berkeley Lab property. Figure 11 shows the condition of Chicken Creek at one of the sample locations. Collectively, these conditions in Chicken Creek do not make it an accessible or attractive recreational area. It is possible that some child could hike in the area and play in the creek, though this is not expected to occur on a routine basis. If contact with the water occurs, exposure could occur via incidental ingestion of water or dermal absorption of tritium along with water.

**Figure 11. Photograph of Chicken Creek Location**

The maximum detected concentration of tritium in Chicken Creek was 563 pCi/L. The drinking water maximum contaminant level (MCL) for tritium is 20,000 pCi/L (EPA 1998a). Thus, tritium concentrations measured in Chicken Creek are less than 3% of the

current drinking water standard. Given these low concentrations relative to health protective concentrations, along with the very low likelihood that children or other individuals in the area would contact Chicken Creek, no surface water exposure pathways will be evaluated further in this assessment.

**Sediment**

Tritium was reported in only one sediment sample at a concentration equal to the detection limit. It was not detected in the duplicate of that sample, and consequently, it is likely that tritium is not present in sediments. If so, no exposures will occur. Even if exposures to tritium occur at the reported level, this will not present a health risk, as the detected concentration is less than 0.003% of the residential direct contact SSL.

**Groundwater**

Tritium is present in groundwater at the Berkeley Lab. However, groundwater at the site and surrounding area is not used for drinking water (EPA 1998a), and no exposure to tritium in groundwater will occur. Transport of tritium in groundwater to surface water, sediment, or air could occur, but this would be reflected in the environmental sampling data for those media. Therefore, no groundwater exposure pathways will be evaluated.

## 3.2 Exposure Quantification

Workers and nearby residents could be exposed to HTO in air via both inhalation and dermal absorption. Though dermal absorption of HTO vapor is recognized by EPA to be an important air exposure pathway for tritium (EPA 1989a), EPA has not developed a separate risk coefficient to address risks associated with dermal exposure. Previously, EPA had incorporated an adjustment factor in the inhalation risk coefficient to account for dermal absorption (EPA 1989a). The updated HTO inhalation risk coefficient does not include this factor (EPA 1999a). However, EPA's Office of Radiation and Indoor Air (Boyd 2001) has indicated that an adjustment factor of 1.5 can be applied to the inhalation risk factor to account for dermal absorption, assuming dermal absorption risks are about half of inhalation risks. Under this approach, dermal exposures and risks are not calculated separately, but instead are included in the inhalation risk calculations.

Inhalation exposures in workers and residents are quantified assuming that both worker and residential populations are chronically exposed to HTO at the levels measured in ambient air surrounding the facility. For the purposes of this assessment, we have divided the sampled area into three distinct segments: non-residential areas, residential areas, and background areas. Risks are assessed for workers in non-residential areas and residents in the residential and background areas. Though individual receptors theoretically could be exposed to tritium in air at any one location throughout their lifetime, EPA (1999b) states that the risk coefficients used to calculate radionuclide exposure risk cannot be applied to individual receptors, but must be applied to exposures

within large populations of receptors. For this reason, we did not evaluate exposures on a location-specific basis, and instead focused on populations within general exposure areas.

Intake is calculated as total pCi accumulated over the exposure period, using the following equation (adapted from EPA 2001):

$$I = C_a * IR * EF * ED$$

***Where***

I = intake (pCi)

$C_a$ = concentration in air ($pCi/m^3$)

IR = inhalation rate ($m^3/d$)

EF = exposure frequency (d/year)

ED = exposure duration (years)

Consistent with EPA guidance (EPA 1989a), exposures are calculated for reasonable maximum exposure (RME) and central tendency exposure (CTE) conditions. Air exposure concentrations for both RME and CTE conditions were calculated by first calculating the time-averaged concentration at each sample location. The time-averaged concentration at each location was calculated by first averaging split pairs within each sample month, and then averaging the results across all three sample months. One-half of the sample-specific detection limit was used for non-detected values. The time-averaged concentration for each sample location is presented in Table 4. The RME concentration for each exposure area (i.e., residential, non-residential, and background) is the maximum time-averaged concentration across all stations within that exposure area. The CTE concentration is the mean time-averaged concentration across all stations within that exposure area. For both RME and CTE conditions, exposure concentrations are assumed to remain constant over the chronic exposure period. In reality, this is an extreme overestimate because it does not take into account the scheduled closing of the NTLF in December 2001. After the NTLF closes, and cleanup is completed, emissions will decrease significantly and HTO concentrations in air should approach regional background levels.

**Table 4. Time-Averaged Tritium Air Concentrations**

| Sampling Location | Time-averaged Tritium Concentrations (pCi/m$^3$) | | |
|---|---|---|---|
| | Location-Specific | Exposure Area Maximum | Exposure Area Mean |
| **Non-residential locations** | | 64.0 | 17.8 |
| ENV-75EG | 64.0 | | |
| ENV-78 | 30.4 | | |
| ENV-LHS | 27.4 | | |
| ENV-77 | 21.3 | | |
| ENV-69 | 15.6 | | |
| ENV-MSRI | 11.2 | | |
| ENV-44 | 6.80 | | |
| ENV-SSL | 9.74 | | |
| ENV-UCBG | 4.50 | | |
| ENV-85 | 2.78 | | |
| ENV-31 | 2.50 | | |
| **Residential locations** | | 4.32 | 3.20 |
| ENV-B13C | 4.32 | | |
| ENV-B13D | 2.72 | | |
| ENV-B13A | 2.57 | | |
| **Background location** | | 4.01 | -- |
| ENV-AR | 4.01 | | |

-- Not calculated. Single sample location.

Both residents and workers are assumed to breathe at a rate of 20 m$^3$/d (EPA 1997, 2001, 2000a), though worker inhalation will be accomplished over a shorter exposure period than in residents (i.e., a work day instead of a 24-hour period). Residents are assumed to be exposed 350 d/yr for 30 years (EPA1997, 2000a), and workers are assumed to be exposed 250 d/yr for 25 years (EPA 1997). For this analysis, the concentrations in indoor air are assumed to be equal to those in outdoor ambient air. In reality, concentrations inside homes or buildings distant from the source could be significantly less than ambient air concentrations.

Table 5 presents the calculated RME and CTE intakes for all three exposure areas. Calculated intakes are greatest in the non-residential areas, which encompass all of the locations immediately adjacent to the NTLF.

## Table 5. Tritium Exposure Concentrations for the Air Pathway

| Exposure Area | Tritium Concentrations (pCi/m$^3$) | | Lifetime Total Tritium Intake (pCi) | |
|---|---|---|---|---|
| | RME[1] | CTE[2] | RME[3] | CTE[3] |
| Non-residential | 64 | 17.8 | 8.00E+06 | 2.23E+06 |
| Residential | 4.32 | 3.20 | 9.07E+05 | 6.72E+05 |
| Background | 4.01 | -- | 8.42E+05 | -- |

-- Not calculated. Single sample location.

[1] Reasonable maximum exposure (RME). Value is maximum time-averaged result reported for all locations within the exposure area.

[2] Central tendency exposure (CTE). Value is the mean value of time-average results for each location within the exposure area.

[3] Tritium intake calculated separately for non-residential and residential locations. Exposures at non-residential locations are calculated for workers assuming a worker breathes at a rate of 20 m$^3$/d, 250 d/yr for 25 yr. Exposures at residential and background locations are calculated assuming a resident breathes at a rate of 20 m3/d, 350 d/yr for 30 yr.

# 4.0 TOXICITY ASSESSMENT

This section presents a summary of the radiotoxicity of tritium and identifies the pathway-specific risk factors to be used to assess excess lifetime cancer risk.

## 4.1 Radiotoxicity of Tritium

The uptake of tritium in humans can occur by exposure to air, water, or food containing tritium. Uptake by way of inhalation of HTO vapor is very efficient, with 99% of that inhaled taken into the body within seconds (NCRP 1979). Skin uptake of tritiated water is correlated with skin temperature, and under resting conditions is generally about equal to the intake by inhalation (NCRP 1979); however, physical activity during exposure will result in approximately twice as much tritium entering the body via inhalation compared to skin absorption (ICRP 1995, NCRP 1979). Once inside the body, the kinetics of HTO follow that of body water. HTO is excreted in the urine, feces, sweat, and breath (Hill and Johnson 1993). The rate at which HTO is eliminated from the body is an important influence on the radiation dose following exposure; biological half-lives for HTO in humans have been reported to be in the range of 6 to 18 days (NCRP 1979).

When living cells are exposed to ionizing radiation, they may absorb some or all of the energy carried by the ionizing radiation. Damage to living cells occurs only when energy is transferred from the radiation to the cells. Tritium does not contain sufficient energy to present an external radiation threat to living tissue, but once inside the body, tritium can potentially cause a number of radiogenic effects (e.g., cancer, genetic effects, developmental abnormalities, and reproductive effects) similar to that observed following whole-body exposure to penetrating radiations such as gamma rays and x-rays. These biological effects of radiation are brought about through chemical changes in the cells caused by ionizations, excitations, dissociations, and atom displacement (Hill and Johnson 1993).

## 4.2 Tritium Cancer Risk Coefficients

EPA (1999a) assumes that radiogenic cancer risk is the limiting risk from radionuclides at Superfund sites. With the exception of two inconclusive epidemiological studies, however, cancer-risk information is not available from human exposures to tritium (Okada and Momoshima 1993). As a result, cancer risk estimates must be obtained using human-cancer data that are available for gamma rays and x-rays together with information on relative biological effectiveness and dose-rate information for tritium obtained from animal studies.

EPA (1999b) has developed risk estimates for tritium based on state-of-the-art methods and models that take into account age and gender dependence of intake, metabolism, dosimetry, radiogenic risk, and competing causes of death in estimating the risks to

health from internal exposures. The cancer risk estimates are expressed as risk coefficients. A risk coefficient for a radionuclide is an estimate of the probability of radiogenic cancer morbidity per unit activity inhaled or ingested. A risk coefficient may be interpreted either as the average risk per unit exposure for persons exposed throughout life to a constant activity concentration of a radionuclide in an environmental medium, or as the population-averaged risk per unit exposure for persons exposed for a brief period to the radionuclide in an environmental medium. The risk coefficients developed by EPA (1999b) apply to populations that approximate the age, gender, and mortality experience characterized by the 1989-91 US decennial life tables. The risk coefficients are not intended for application to specific individuals, ages, or genders. However, because the difference between an age and gender-averaged inhalation risk coefficient and an adult-only inhalation risk coefficient would be slight, EPA's Office of Radiation and Indoor Air (Boyd 2001) has stated that it is appropriate to use the risk coefficients to address risks in adult-only populations, such as the workers in the vicinity of NTLF.

Risk coefficients are specific to the radionuclide, the environmental medium, and the mode of exposure through that medium. EPA (1999b, 2000b) has published risk coefficients for internal exposure to HTO in a variety of media, including air. The risk coefficient for inhaled HTO is $5.62 \times 10^{-14}$ (risk/pCi).

EPA has not developed a risk coefficient for dermal exposure to HTO in air. However, as mentioned previously, EPA's Office of Radiation and Indoor Air (Boyd 2001) has indicated that an adjustment factor of 1.5 can be applied to the HTO inhalation risk factor to account for dermal absorption of HTO in air. This adjustment factor assumes that dermal exposures and risks are about half that of inhalation risks. If air exposures occurred under completely restful conditions, dermal uptake could equal inhalation uptake. The calculated inhalation risk factor adjusted to account for dermal uptake at a rate of 50% of inhalation intake is $8.43 \times 10^{-14}$. This risk factor will be used to address risks from exposure to HTO in air.

EPA (199b, 2000b) also has developed risk coefficients for organically bound tritium in a variety of environmental media, which are approximately a factor of two greater than those for HTO. These values are not used here to assess ambient air risks because OBT is not present in NTLF emissions or in ambient air.

# 5.0 RISK CHARACTERIZATION

For a given exposure scenario, lifetime cancer risk (R) associated with the intake of a given radionuclide is calculated by multiplying the applicable risk coefficient (r, as Risk/pCi) by the per capita activity intake (I, as pCi). Thus,

$$R = r * I$$

## 5.1 Human Health Risks from Exposure to Tritium

Table 6 presents the calculated risks for non-residential, residential, and background exposure areas for both RME and CTE conditions. RME risks range from $6x10^{-7}$ to $7x10^{-8}$, being greatest in the non-residential exposure areas and least in the background area. CTE risks demonstrate a similar pattern and range from $2x10^{-7}$ to $6x10^{-8}$. Air exposure contributes almost all of the total health risk from environmental tritium at and around the Berkeley Lab. Tritium levels in soil, even in the maximum concentration areas near the NTLF stacks, are 2 to 3 orders of magnitude below risk-based soil screening levels developed for the protection of human health, and therefore do not contribute significantly to overall risks. Surface water and sediment exposures also do not contribute significantly to risks given the no or low detected tritium levels and/or the low likelihood that these water bodies would be used recreationally. Groundwater exposure will not occur, as groundwater is not used as a public water source in the vicinity of the site. Exposure to tritium from the ingestion of produce grown on local residential soil is theoretically possible, but tritium was not detected in the soil samples collected from any residential location, so this pathway was not included. Tritium can be present in locally grown produce as a result of water vapor uptake directly from air. As mentioned previously, however, this pathway does not contribute significantly to overall risks. Even assuming a local resident ingests nothing but homegrown produce for an entire lifetime (which is highly improbable in the area surrounding the site), risks associated with this pathway[7] are in the range of $10^{-8}$ to $10^{-9}$.

Overall, site risks are calculated to be in the range of $10^{-7}$ or less.

## 5.2 Uncertainty Analysis

As in any risk assessment, there are uncertainties associated with the risk estimates presented here that stem from the use of assumptions, judgment and incomplete data. In general, risk assessment is structured so that risks will not be underestimated. Key uncertainties are discussed below for each of the principal steps in this risk assessment. These uncertainties vary in magnitude and direction, but collectively do not change the overall conclusions of the assessment, as the risks presented here were calculated using conservative assumptions in most cases.

**Table 6. Tritium Risks for the Air Pathway**

| Exposure Area | Lifetime Total Tritium Intake (pCi) | | Tritium Risk Coefficient[1] | Lifetime Excess Total Cancer Risk | |
|---|---|---|---|---|---|
| | RME [2] | CTE [2] | | RME | CTE |
| Non-residential | 8.00E+06 | 2.23E+06 | 8.43E-14 | 7.E-07 | 2.E-07 |
| Residential | 9.07E+05 | 6.72E+05 | 8.43E-14 | 8.E-08 | 6.E-08 |
| Background | 8.42E+05 | -- | 8.43E-14 | 7.E-08 | -- |

[1] Risk Coefficient reported in EPA (2000b) multiplied by 1.5 to account for dermal exposure risks (Boyd 2001).
[2] Tritium intake calculated separately for non-residential and residential locations. Exposures at non-residential locations are calculated for workers assuming a new worker breathes at a rate of 20 $m^3$/d, 250 d/yr for 25 yr. Exposures at residential locations and background locations are calculated assuming a resident breathes at a rate of 20 $m^3$/d, 350 d/yr for 30 yr.

## Exposure Assessment

- **Environmental tritium levels.** This assessment assumed that the environmental tritium levels detected during the 2001 supplemental sampling were representative of typical environmental conditions at the facility. It is possible that the measured levels do not reflect typical conditions. For example, air samples were collected during a 3-month period and therefore are not necessarily representative of long-term average concentrations. Concentrations could be higher or lower depending upon site emissions and local meteorological conditions. However, the 2001 air sampling results are generally consistent with the results of the long-term annual monitoring conducted as part of compliance monitoring activities at the Berkeley Lab. These data show that ambient levels have been declining, primarily due to engineering changes made in facility operation since 1990. Following closure and decontamination of the NTLF, the ambient air levels will decline further. Therefore, it is considered most likely that the 2001 supplemental air data are representative of tritium air concentrations under typical site conditions. Surface water concentrations also could increase if additional groundwater or surface flow input occurred as a result of increased precipitation. However, streams were sampled during the spring, which is generally a wet time of year. Therefore, significantly increased tritium loading to area streams is probably unlikely.

- **Exposure concentrations.** This assessment assumed that environmental tritium concentrations would remain constant throughout the 25 to 30-year

exposure periods used in this assessment. This is probably an overestimate of exposure concentrations, however, as the NTLF is scheduled to close in December 2001. Once the Facility has been closed out and cleaned up, tritium emissions will decrease significantly, tritium in air will disperse or deposit to the surface, and tritium in surface environments will undergo decay to nonradioactive helium. The half-life of tritium is 12.3 years. Overall, exposure concentrations during the 25 to 30-year period following the NTLF shutdown will be less than those measured during 2001 additional sampling.

- **HTO dermal absorption from air.** As mentioned earlier, EPA has not developed a risk coefficient to address dermal HTO uptake from air. In this assessment, it was assumed that dermal exposures and risks were approximately half that of inhalation, based on recommendations from EPA (Boyd 2001). However, under resting conditions, dermal exposures could equal inhalation exposures. If all exposures were to occur in a resting state, the risks presented in this report would be underestimated by 25%. However, it is unlikely (if not improbable) that individuals within the potentially exposed worker or residential populations would remain in a resting state throughout the course of the entire 25 to 30-year exposure period. Therefore, it is considered unlikely that dermal exposures and risks from airborne tritium have been underestimated.

- **Land Use.** The risk assessment was conducted under the assumption that land use would not change in the future, even after the NTLF is closed in December 2001. This is considered a reasonable assumption, given that the entire Berkeley Lab is under long-term lease to the DOE.

**Radiotoxicity Assessment**

- **HTO inhalation risk coefficient**. The inhalation risk coefficient for tritium was calculated using methods and models that take into account age and gender dependence, intake, metabolism, dosimetry, radiogenic risk, and competing causes of death in estimating the risks to health from internal exposures. Many assumptions are necessary when making these calculations, which introduce uncertainty into the risk coefficient. However, tritium uptake and distribution in the body is relatively well understood except for a long-term component that contributes little to dose (EPA 1999b), so this contributes minimally to uncertainty. There are uncertainties, however, in the models used to project cancer risk over multiple tissues. The assumptions made could over- or underestimate risk.

**Risk Characterization**

- **Risks of non-cancer effects.** Consistent with EPA guidance, this assessment only evaluated the risk of contracting cancer from exposure to tritium. Radiation from tritium can cause other adverse effects (e.g., developmental, genetic), and the risk of these effects was not estimated. However, EPA has determined that cancer is the risk-driving endpoint in radiological risk assessments. Therefore, though risks are potentially underestimated, they should not be substantially so.

- **Risks from in utero exposures.** EPA's risk coefficients are lifetime-averaged values, based on exposures from birth. In utero exposures are not factored into the risk coefficients, though they can contribute to certain cancer rates. This could result in an underestimate of risk.

## 5.3 Risk Context

The predicted risks from exposure to environmental tritium at the Berkeley Lab are in the range of $10^{-7}$ to $10^{-8}$. These risks fall below EPA's risk range of $10^{-4}$ to $10^{-6}$ for risk management action at NPL sites (40 CFR 300.430(e)(2)(A)(*2*)). As a general policy, EPA typically uses the results of the baseline risk assessment to establish the basis for taking a remedial action at Superfund sites. Generally, where the baseline risk assessment indicates that a cumulative site risk to an individual using reasonable maximum exposure assumptions for either current or future land use exceeds the $10^{-4}$ lifetime excess cancer risk end of the risk range, action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is warranted at the site. For sites where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is in the range of $10^{-4}$ to $10^{-6}$, action generally is not warranted (EPA 1991b). In some instances, action may be taken to protect public health if a chemical-specific standard that defines acceptable risk is violated or there are unacceptable noncarcinogenic effects, but neither of these conditions exists at this site: the NTLF and Berkeley Lab are in compliance with all regulatory standards and programs, and tritium does not pose noncarcinogenic hazards that are greater than the predicted cancer risks.

Other risk assessment activities have also been performed in conjunction with tritium releases from the NTLF. As noted above, an annual assessment is conducted under the NESHAPs program to determine the tritium dose to a hypothetical maximally exposed individual (MEI). These assessments have been consistently orders of magnitude below the NESHAPs standard. For example, in 1998, the dose to the MEI from the NTLF was 0.27 mrem/year. This declined to 0.067 mrem/year in 1999 and 0.057 mrem/year in 2000, compared to the NESHAPs standard of 10 mrem/year (LBNL 1998, 1999, 2001e). The tritium NESHAPs is considered to be an ARAR in the context of Superfund (EPA

1989b). Compliance with ARARs is one of the threshold requirements for evaluating a proposed remedy under the National Contingency Plan (40 CFR 300.430(e)(9)(B)). Thus, the emissions from the facility comply with the Clean Air Act requirements of NESHAPs and the ARARs requirement of Superfund.

In 1997, the Berkeley Lab performed a comprehensive multipathway risk assessment for tritium exposure using risk assessment methodologies developed by the DOE (LBNL 1997). The lifetime excess cancer risks associated with a hypothetical tritium exposure related to an NTLF tritium air emission rate of 100 curies per year range from $6 \times 10^{-5}$ (on-site workers) to between $0.9 \times 10^{-6}$ and $6 \times 10^{-6}$ for off-site residents. (100 curies per year is larger than the current annual release of about 20 curies per year.) Although this assessment was not conducted in accordance with EPA guidance, the hypothetical receptors chosen for this risk assessment are equivalent to EPA's Reasonable Maximum Exposed (RME) individual. Thus, the results of the Berkeley Lab assessment corroborate the current assessment conducted in accordance with EPA guidance.

The overall conclusion of these assessments, consistent with the conclusions presented in this document, is that the tritium emissions from the NTLF meet the two threshold requirements of Superfund – protection of human health and compliance with ARARs. Therefore, based on EPA policy and the predicted risk levels, tritium emissions do not pose a significant risk to human health or to the environment.

## 6.0 ECOLOGICAL ASSESSMENT

Plants and animals inhabiting the lands and creeks surrounding the NTLF also can be exposed to environmental tritium. The Department of Energy (DOE) has established a radiation dose protection standard of 1 rad/day for aquatic organisms (DOE 1993). In addition, the International Commission on Radiological Protection (ICRP) has established a radiation dose limit of 0.1 rad/day for terrestrial plants and animals (ICRP 1977).

To assist in demonstrating compliance with these limits at its sites, DOE issued an interim technical standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, in June 2000. Along with other institutions in the DOE complex, Berkeley Lab was asked to review and comment on the proposed standard. As part of the review, results of environmental monitoring at Berkeley Lab were compared to the standard biota concentration guides. Results of this preliminary assessment show that concentrations of radionuclides in environmental media at Berkeley Lab are orders of magnitude less than those listed in the DOE guide. This indicates that animals and plants are protected at levels well below the recommended dose limits (LBNL 2001f).

This finding is consistent with those of the International Atomic Energy Agency (IAEA 1992), which concluded that radionuclide releases that do not result in adverse human health risks would not harm biota. The only exceptions to this conclusion were situations in which a threatened or endangered species is present or where special land-use restrictions were required to achieve acceptable human health risks. No land use restrictions are in place at the Berkeley Lab. Further, no endangered and threatened species exist at the site. Though a portion of the site is within a 407,000-acre zone designated by the U.S. Fish and Wildlife Service as a critical habitat for the endangered Alameda whipsnake, no Alameda whipsnake sightings have been reported on Berkeley Lab property. Several threatened or endangered species inhabit San Francisco Bay, but they are located 12 miles from the Strawberry Creek discharge (EPA 1998[a]). Further, no tritium from the NTLF has been detected in Strawberry Creek at its discharge point to San Francisco Bay.

Based on this, aquatic and terrestrial wildlife are not predicted to be at risk from exposure to environmental tritium associated with the NTLF.

# 7.0 SUMMARY AND CONCLUSIONS

This report evaluated risks associated with environmental tritium releases from the NTLF at the Berkeley Lab, in Berkeley, California. This report was prepared to supplement information being supplied by the Berkeley Lab to DOE and to EPA for the Agency's determination of whether the Lab should be added to the NPL under the federal Superfund Program. The risk evaluation followed EPA guidelines for conducting baseline risk assessments at NPL sites, and was based on supplemental sampling data collected during 2001 to satisfy EPA and stakeholder groups' requests for more data on environmental tritium in the vicinity of the NTLF. Samples were collected from all environmental media at and surrounding locations of likely maximum concentration. Risks were evaluated for all potential receptors and exposure pathways.

The principal pathways by which humans can potentially be exposed to environmental tritium in the vicinity of the NTLF are via inhalation and dermal absorption of tritiated water vapor (HTO) that is present in ambient air. No other pathways are complete or contribute substantially to risk.

Intake associated with potential inhalation and dermal exposure to airborne HTO was calculated for three receptor populations: Berkeley Lab workers located closest to the NTLF, nearby residents, and residents at a background location. Exposures were calculated assuming workers and residents were exposed for 25 and 30 years, respectively, consistent with EPA Superfund guidance. Ambient air concentrations during these exposure periods were conservatively assumed to remain unchanged, even though the NTLF is scheduled to close in December 2001.

Risk coefficients developed by EPA were used to calculate excess lifetime risk associated with airborne exposure to HTO. Total excess lifetime cancer risks from inhalation and dermal absorption of airborne HTO were calculated to be in the range of $10^{-7}$ to $10^{-8}$. These risks fall below EPA's risk range of $10^{-4}$ to $10^{-6}$ for risk management action at Superfund sites, and will likely be even lower following the closure of the NTLF. In addition, environmental tritium associated with the NTLF does not pose a noncarcinogenic hazard or a risk to ecological receptors at the site or surrounding area.

The collective results of supplemental environmental sampling interpreted by this baseline risk evaluation demonstrate that the tritium concentrations at the Berkeley Lab are well below the ARARs that would apply under Superfund, and that environmental tritium associated with the NTLF at the Berkeley Lab does not pose any risk that would require remedial or response activities under the federal Superfund program. These results corroborate the results of prior risk assessments and public health evaluations, which demonstrate that the operation of the NTLF does not pose a significant risk to human health or the environment. The results also are consistent with NESHAPs requirements. For these reasons, the Berkeley Lab should not be considered for inclusion on the NPL.

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